Report on

THE ENIAC

(Electronic Numerical Integrator and Computer)

Developed under the supervision of the
Ordnance Department, United States Army

MAINTENANCE MANUAL

UNIVERSITY OF PENNSYLVANIA
Moore School of Electrical Engineering
PHILADELPHIA, PENNSYLVANIA

June 1, 1946

A REPORT ON THE ENIAC

(Electronic Numerical Integrator and Computer)

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THE MAINTENANCE MANUAL

by

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PREFACE

The Report on the ENIAC consists of five separately bound parts, as follows:

1. ENIAC Operating Manual

2. ENIAC Maintenance Manual

3. Part I, Technical Description of the ENIAC

   Volume I (Chapters I to VI)

4. Part I, Technical Description of the ENIAC

   Volume II (Chapters VII to XI)

5. Part II, Technical Description of the ENIAC

Included with the Operating Manual and Parts I and II of the Technical Description are all drawings (see table 0.3 below) which are required for understanding these reports. The Maintenance Manual assumes access to the complete file of ENIAC drawings.

Part I of the Technical Description is intended for those who wish to have a general understanding of how the ENIAC works, without concerning themselves with the details of the circuits; it assumes no knowledge of electronics or circuit theory. Part II is intended for those who require a detailed understanding of the circuits. Its organization, to a great extent, duplicates that of Part I so as to make cross referencing between the two parts easy.

The ENIAC Operating Manual contains a complete set of instructions for operating the ENIAC. It includes very little explanatory material, and hence assumes familiarity with Part I of the Technical Description of the ENIAC. The ENIAC Maintenance Manual includes description of the various test units and procedures for testing, as well as a list of common and probable sources of trouble. It assumes a complete understanding of the circuits of ENIAC, i.e. a knowledge of both Parts I and II of the Technical Description of the ENIAC.

The Report on the ENIAC and the complete file of ENIAC drawings constitute a complete description and set of instructions for operation and maintenance of the machine. The drawings carry a number of the form PX-n-m. The following tables give the classification according to this numbering system.

TABLE 0.1

Values of n	Division
1	General
2	Test Equipment
3	Racks and Panels
4	Trays, Cables, Adaptors, and Load Boxes
5	Accumulators
6	High Speed Multiplier
7	Function Table
8	Master Programmer
9	Cycling Unit and Initiating Unit
10	Divider and Square Rooter
11	Constant Transmitter
12	Printer
13	Power Supplies

TABLE 0.2

Values of m	Subject
101-200	Wiring Diagrams
201-300	Mechanical Drawings
301-400	Report Drawings
401-500	Illustration Problem Set-Ups.

The reader of this report will be primarily interested in the types of drawings listed in the following paragraphs. A table on page 4 gives the corresponding drawing number for each unit of the ENIAC.

1) Front Panel Drawings. These drawings show in some detail the switches, sockets, etc., for each panel of each unit. They contain the essential instructions for setting up a problem on the ENIAC.

2) Front View Drawings. There is one of these drawings for each kind of panel used in the various units of the ENIAC. These show the relative position of the trays and the location of the various neon lights. Since these drawings show the neon lights, they can be used to check the proper operation of the various units.

3) Block Diagrams. These drawings illustrate the logical essentials of the internal circuits of each unit. That is, resistors, condensers, and some other electrical details are not shown; but complete channels (paths of pulses or gates representing numbers or program signals) are shown in all their multiplicity. These drawings will be of interest to those who are interested in Parts I and II of the Technical Report.

4) Cross-section Diagrams. These drawings are electronically complete except that only one channel is shown where there is more than one. Thus, these drawings show every resistor and condenser and any other electronic elements belonging to any circuit. These drawings will be of particular interest to the maintenance personnel and to those reading Part II of the technical report.

5) Detail Drawings. All other drawings of the ENIAC come under this heading. A complete file of drawings is available at the location of the ENIAC.

Table 0.3
ENIAC DRAWINGS

Unit	Front Panel	Front View	Block Diagram	Cross - Section
Initiating Unit	PX-9-302 9-302R	PX-9-305	PX-9-307	
Cycling Unit	PX-9-303 9-303R	PX-9-304	PX-9-307	
Accumulator	PX-5-301	PX-5-305	PX-5-304	PX-5-115
Multiplier	PX-6-302 6-302R 6-303 6-303R 6-304 6-304R	PX-6-309	PX-6-308	PX-6-112A 6-112B
Function Table	PX-7-302 7-302R 7-303 7-303R	PX-7-305	PX-7-304	PX-7-117 7-118
Divider and Square Rooter	PX-10-301 10-301R	PX-10-302	PX-10-304	
Constant Transmitter	PX-11-302 11-302R 11-303 11-303R 11-304 11-304R	PX-11-306	PX-11-307	PX-11-116 11-309 (C.T. and R.)
Printer	PX-12-301 12-301R 12-302 12-302R 12-303 12-303R	PX-12-306	PX-12-307	PX-12-115
Master Programmer	PX-8-301 8-301R 8-302 8-302R	PX-8-303	PX-8-304	PX-8-102

Other drawings of particular interest:

Floor Plan	PX-1-302	IBM Punch and	PX-12-112
A.C. Wiring	PX-1-303	Plugboard	PX-12-305
IBM Reader and	PX-11-119	Pulse Amplifier and	PX-4-302
plugboard	PX-11-305	Block Diagram	PX-4-301

Interconnection of Multiplier and Accumulators PX-6-311
Interconnection of Divider and Accumulators PX-10-307

The front view drawings and the large front panel drawings (whose numbers do not end with "R") are bound as a part of the Operator's Manual.

Included with the report is a folder containing all the drawings listed in the above table except the large front panel (see above). A complete file of drawings is available at the location of the ENIAC.

I. INTRODUCTION TO MAINTENANCE MANUAL

1.1 Structure of Maintenance Manual

The maintenance manual devotes a chapter to each unit of the ENIAC including one chapter to the a-c supply circuits. These various chapters were written by the people who designed or helped to design the respective unit.

Each chapter contains a list of the wiring diagrams and test charts referring to the circuits of that particular unit. It contains a section giving a testing procedure for the particular unit. Note that test procedures for each unit are also given in the operating manual. In each chapter there is also a list of possible failures and their remedies. As time goes on the conscientious maintenance man will do well to keep a log book listing for each unit failures encountered, their symptoms, and the remedy.

1.2 Notes and Warnings to Maintenance Personnel

1) Keep in touch with operating group for any trouble which may develop. Note repairs and troubles in log book. Keep log of all tube failures - list each tube.
2) This machine contains a number of dangerously high voltages. Avoid working on any part while DC is on.
   Do not leave off any covers. Remember the shells of the metal tubes are at high potential with respect to the frame.

3) Never operate machine with any DC fuses out except for special tests. When replacing a DC fuse be sure they are put in correctly - i.e. washer in cupface out.

4) Make periodic check on ventilating fans.

5) Do not pound on plugs or plug-in units to get them in; use steady pressure. Avoid pulling on wires or cables to remove plugs; use case for grip.

6) Keep covers on relays as much as possible; replace in same position to avoid spilling onto relay contacts dust which may have collected.

7) Return all plug-in units and cables to proper racks when not in use.

8) <u>DONT'S</u>

   (a) DON'T leave doors or coverplates leaning against relays or tubes or front panels.

   (b) DON'T hang probes on wires in trays.

   (c) DON'T mark panels with chalk or stick paper labels on them.

   (d) DON'T drop solder, nuts, lock washers, etc., inside machine and leave them there. GET THEM OUT!

1.3 <u>General Remarks on Testing</u>

1.3.1 Standard Test Problems

Standard test problems check for continuity of the programming set-up unless there are attached subsequences which operate simultaneously. Generally a standard test problem cannot be designed so as to test the numerical circuits completely. However, it comes much closer to completely

checking the program control and common programming circuits.

1.3.2 Systematic Unit Tests

Systematic tests such as those described in the operating manual are designed to check the numerical circuits and common programming circuits. If repeated with different program controls, they check the program control circuits. The chapters of this manual give some other testing methods for certain of the units.

1.4 Responsibility of Maintenance Personnel

1) To have studied the four manuals (Operating Manual, Technical Reports I and II, and the Maintenance Manual) sufficiently to thoroughly understand the operation of each unit and the operating of the ENIAC as a whole.

2) Knowing that a particular unit is failing to be able to find and remedy that failure.

3) Knowing of the existance of a failure in the ENIAC to be able to assist the operating personnel in localizing the failure to particular units. However, the duty of isolating numerical and programming failures to a particular unit belongs primarily to the operating personnel.

1.5 ENIAC Drawings

The maintenance personnel should have access to a file of drawings at the location of the ENIAC. As part of the file of drawings there is a complete catalog of all the drawings of the ENIAC. Only a few of the drawings are referred to in the various reports and in case of difficulty with particular circuits the maintenance man should refer to the catalog for

any other drawings which may be of help.

Drawings which will be of particular help for maintenancing will be the various block diagrams and the cross-section diagrams of each unit.

1.6 General Remarks on Trouble Shooting

After a test problem has indicated a failure it becomes a problem of localization.

1.6.1 Find the Unit that Failed

To the operating personnel the type of failure found in the test problem may indicate the unit (or kind of unit) in which the failure occurred. Various unit tests (such as those described in the operating manual) may be performed to assist in this localization process.

1.6.2 Finding the Circuit that Failed

The various unit tests are designed to localize the failure to a particular circuit. Complete knowledge of part II of the technical report and efficient use of block diagrams will help in this process.

1.6.3 Circuit Failures

The most frequent failure in circuits is burned out tubes. Replace tubes in suspected circuits and test the tubes removed (see Section on use of the tube tester). Note that cathode failures in metal case tubes can be detected at removal time by comparing case temperature with that of other tubes.

If all the tubes in the suspected circuits test all right a static test of the circuits is indicated to check against failures in wiring, resistors, or condensers. To assist in static and dynamic testing test charts have been prepared and certain test equipment built (see

The charts have detailed instructions giving switch settings, voltages,

pulse rise, duration, and fall times, pulse amplitudes, et cetera.

The following principles in trouble shooting are worth noting.

1) If a circuit operates when it shouldn't look for failure of an inverter tube.

2) If a circuit does not operate when it should look for failure of a gate or a buffer.

1.7 Transient Failures

Transient failures can usually be found by repeated programming of the suspected unit. As explained below certain test equipment has been built to assist in finding transient failures.

Practically all circuits in the ENIAC were designed with at least a 2 to 1 safety factor. Thus, parameters (such as loads, voltages, et cetera) can be varied considerably without effecting the operation of a normal unit.

Thus, to assist in finding transient failures certain test equipment (namely, a variable oscillator and variable power supply equipment) has been built. The variable oscillator can be plugged into the cycling unit and the ENIAC operated at frequencies above or below the standard frequency of 100 kc. The variable power supply can be used to vary the voltages in a unit and thus increase the probability of failure.

II. INITIATING UNIT

2.1 Circuits of the Initiating Unit

Tables 2.0 and 2.1 give a list of drawings pertaining to the Initiating Unit. The Interconnection diagram, PX-1-301, shows the location of the plug-in units and gives the numbers of the chassis drawings.

Table 2.0

INITIATING UNIT PLUG-IN UNITS

No. of units used in Initiating Unit	Plug-in Unit	Wiring Diagram	Static and Dynamic Test Chart
19	Cycling Unit Transmitters	PX-9-102A	PX-9-123
6	Transceivers	PX-5-147	PX-5-129
2	Initiating Pulse Units	PX-9-105	PX-9-125
1	Reader- Printer Starting Unit	PX-9-104	PX-9-122
1	Reader Interlocking Unit	PX-9-103	PX-9-124
1	Reader Transmitter Unit	PX-9-106	PX-9-121

Table 2.1 OTHER INITIATING UNIT CIRCUITS		
Name	Wiring	Static Test Chart
Oscilloscope	PX-9-115	PX-9-126
DC Voltmeter	PX-9-118, 119 A, 119B	
Initial Clear Relay	PX-9-115, 119	
AC Voltmeter	PX-9-118A, 119	
Start, Stop, and Door Switch Shunt	PX-9-119 (see Block Diagram PX-9-307)	

2.2 Testing Program

Tests for each of the plug-in units are described on the test charts listed and covered in the section on the use of the Test Bench.

Tests on the plug-in units in place in the unit are outlined below.

A) Cycling Unit Transmitters

With cycling unit on continuous operation observe CPP, 9P, 1'P, RP on Oscilloscope on cycling unit. Presence of pulses of at least one inch amplitude and equal width for each pulse indicates all is well. If not replace one or more of the associated cycling unit transmitters. If no pulse at all, check on gates which produce the missing pulses for presence of pulse at output. Block diagram PX-9-307 will be most useful here.

B) Selective Clear Transceivers

Connect each to a program line carrying continuous program pulses, then observe neon lights. If any unit fails, replace it.

C) Initiating Pulse Units

One of these units is used to produce a pulse synchronized with the Eniac when the initiating pulse switch is pushed. The other produces a synchronized pulse when the printer finishes an operation. To check the first, connect output to input of one selective clear transceiver, set cycling unit on 1 add operation. Push initiating pulse switch, upper neon should light; pulsh 1 pulse 1 add switch, lower neon should light, push 1 pulse 1 add switch again, both neons out and transceiver neon should light.

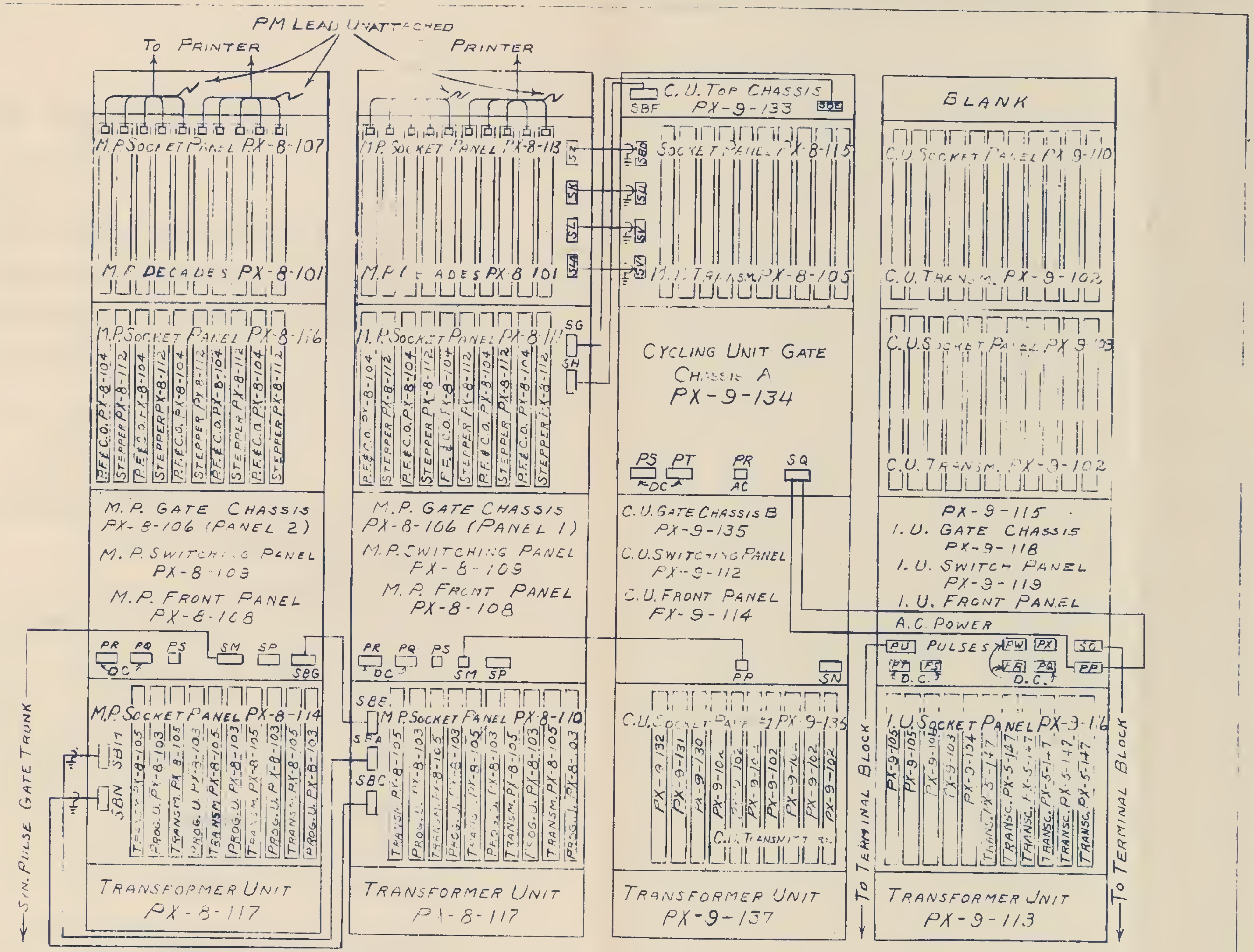
To test the other, connect printer into a program chain. This will also test printer section of Reader-Printer Starting Unit.

D) To test Reader-Printer Starting Unit, Reader Interlocking Unit, Reader Transmitter Unit, plug reader output into selective clear transceiver to check presence of output pulse. Set Cycling Unit on 1 add time. Push reader start switch, reader start neon on, reader interlock neon on, IBM reader should feed card, reader finish neon on. After card feed push 1 add button, reader start neon out, reader synchronizing neon on. After next 1 add push reader interlock neon out, reader synchronizing neon out, transceiver neon on.

E) The Oscilloscope section needs no special mention as to service. The standard tests for the RCA 155A' scope are applicable with the exception that the sweep frequency operates at approximately 60 CPS.

F) Servicing of the two voltmeter circuits is straightforward - checks for open circuits, short circuits, rosin joints, loose connection, etc.

G) The initial clear relay circuits are shown on PX-9-307. The time constant of the condenser relay circuit is sufficient that the relay should stay closed for not less than 1/2 second. In case of trouble look for failure of condenser or relay.



INTERCONNECTION DIAGRAM OF MASTER PROGRAMMER, CYCLING UNIT, & INITIATING DEVICES

1. TRANSFORMER UNIT IN PANEL 1 WAS PX-8-114; TRANSFORMER UNIT IN PANEL 2 WAS PX-8-110. J. Cummings 2/7/45
2. INTERCONNECTIONS REVISED & PLUGS ADDED. T.K.S. 4/18/45
3. MASTER PROGRAMMER PANELS & INITIATING UNIT PANEL BROUGHT UP TO DATE. CYCLING UNIT GATES RENUMBERED, SBE & SBF, PR, PS, PT, INDICATED. DECADE STATIC OUTPUT CABLES OF M.P. SHOWN. J. Cummings 8-21-45

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M.P., C.U. & I.U. INTERCONNECTION DIAGRAM

MATERIAL	FINISH	SCALE	
Drawn by: CJMcC JAN. 1, 1945	Checked by: R.F.S. 11 Jan 45	Approved by: T.K. Sharpless 1-11-45	PX-1-301

III. CYCLING UNIT

3.1 Circuits of Cycling Unit

The cycling unit panel includes ten transmitter plug-in units of the master programmer (see Chapter X) as well as the circuits of the cycling unit proper. The following tables and PX-1-301 give the pertinent drawings and show the position of the plug-in units.

Table 3.1

PLUG-IN UNITS

Number of Units	Name	Wiring Diagram	Static and Dynamic Test Charts
10	**Master Programmer Transmitters**	PX-8-105	PX-8-122
6	Cycling Unit Transmitters	PX-9-102A	PX-9-123
1	Cycling Unit Carry Gate Transmitter	PX-9-102B	PX-9-123
1	Cycling Unit Off-beat Unit	PX-9-130	PX-9-139
1	Cycling Unit Oscillator	PX-9-131	PX-9-140
1	On-beat Unit	PX-9-132	PX-9-141

Table 3.2

CHASSIS CIRCUITS

Name	Position (tubes)	Wiring	Test Chart
Top chassis	1 and 2	PX-9-133	Static: PX-9-128
Gate A	21 to 40	PX-9-134	PX-9-128A
Gate B	41 to 60	PX-9-135	Dynamic: PX-9-129

3.2 Testing Procedure

The routine testing of the cycling unit is best carried out in the following manner. With the operations switch on continuous and the oscillator switch on Internal, the various pulses and the carry gate are examined on the viewing scope. Their presence is not sufficient for satisfactory operation but the pulses must all be of approximately the same shape and all signals at least one inch high. Next, the external oscillator should be plugged in and the switch set to External, the tens pulses should be examined on the viewing scope. The frequency should be increased until either a shift of 1 pulse to the right is observed in the tens pulses or one or more neon bulbs in cycling unit ring glow. The frequency at which this occurs should be at least 160 kc. At this top speed the other pulses and gate should be again examined. The most common difficulty in the cycling unit is failure of the ring to count at these high frequencies. This can usually be traced to trouble in the ring pulse standardizer.

The 1 addition time mode of operation as well as the one pulse time mode must also be tested. Test the 1 add mode at 100 kc and also at the top

frequency. Presence of the tens pulses must also be checked. This is done by programming a chain of two programs, one event of which is to tell an accumulator to transmit. Then, continued pushing of the 1 pulse 1 add switch should result in the program chain stepping along and on the one program, the accumulator cycling, as evidenced by the neons flashing, but the same number remaining in the accumulator. The same test should be made under 1 pulse time operation requiring, of course, 40 pushes of the switch to go through the two program sequence. Should any of the above tests fail the 1 add gate, ring stop gate, 10 pulse flip-flop, and 10 pulse gate should be investigated first.

Trouble in the Viewing Scope may result from disturbed DC voltages which are produced in the top panel or due to failure of the sweep circuit which is located on Gate Chassis B, PX-9-135. This circuit is similar to one used in the A-R Scope, type 256B, but uses different tubes. A discussion of this type of circuit will be found in the A-R Scope Manual.

IV. ACCUMULATOR

4.1 Accumulator Circuits

The following tables and PX-5-302 give the numbers of drawings and the location of various accumulator circuits.

Table 4.1

ACCUMULATOR PLUG-IN UNITS

Number of Units	Plug-in Unit	Wiring Diagram	Static and Dynamic Test Chart
10	Decade	PX-5-133	PX-5-126
1	PM Clear	PX-5-108	PX-5-127
2	Receiver	PX-5-148	PX-5-128
8	Transceiver	PX-5-147	PX-5-129
1	Repeater	PX-5-149	PX-5-120

Table 4.2

ACCUMULATOR DRAWINGS

Name	Position (tubes)	Wiring	Test Chart
Gate Chassis	41 to 60	PX-5-117	Static: PX-5-123 Dynamic: PX-5-124

4.2 Testing Procedure

4.2.1 Numerical Circuits

(a) Receiving failures.

Using the accumulator test cards described in the operating manual (section 2.2) the constant transmitter can be used to transmit numbers into an accumulator.

In case of failure in this sort of test, there are two possible procedures:

1) Shift to another input and repeat the test.

2) Program a transmission at one pulse time speed.

Either of these procedures will generally determine whether the failure is in the decade unit or in the input gate circuits. If the failure is in the decade unit replace it (repairing of plug-in units is discussed in the section on the test bench, Chapter XII).

Any systematic test should involve receiving numbers on all five inputs.

4.2.2 Transmission Failures

With a number such as P 44444 44444 in the doubtful accumulator, it should be programmed to add its contents to another accumulator at a one pulse time rate. The receiving accumulator should be known to be operating correctly, of course.

Consecutively, or simultaneously by using a second accumulator to receive, the subtract transmission circuits can be checked.

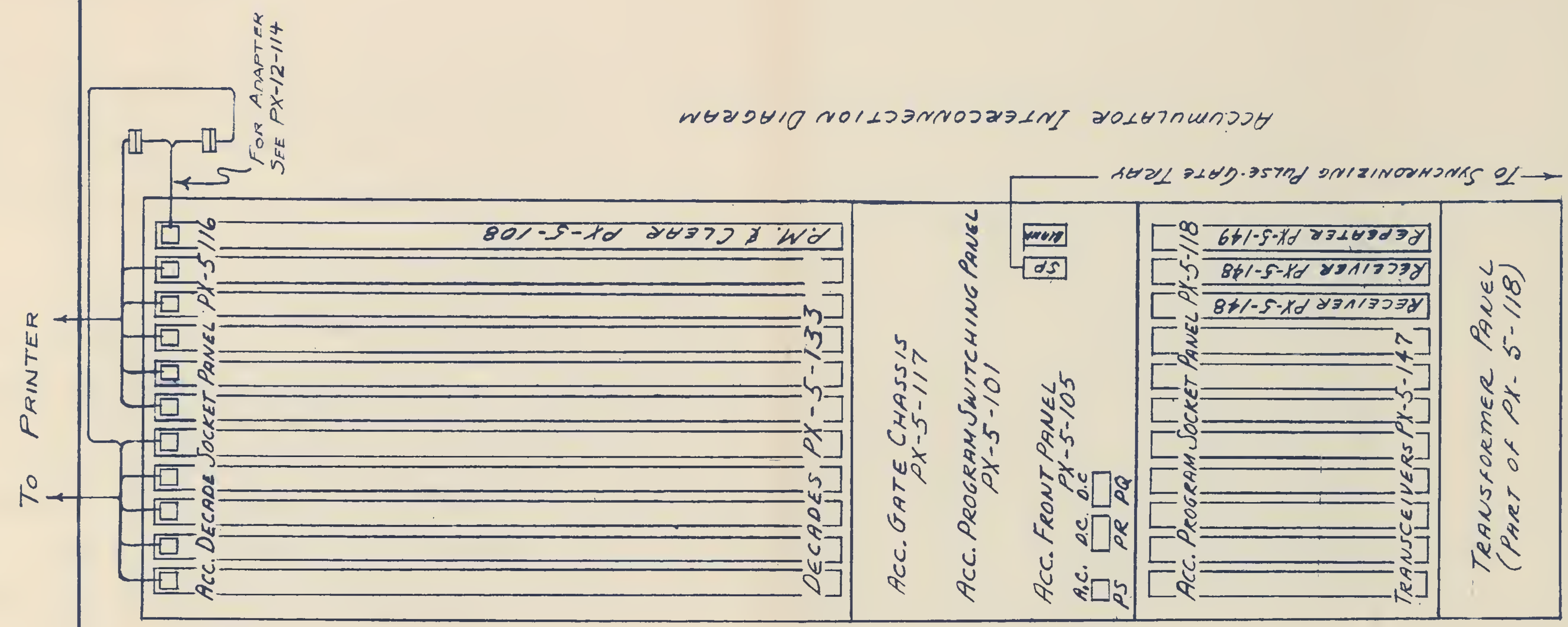
4.3 Common Programming Circuits

Simultaneously failure in all ten channels (or eleven channels in some cases) persisting with various program controls indicates failure

in common programming circuits.

4.4 Program Control Failure

If only one fails replace it. If more than one transceiver fails look for trouble in common programming circuits perhaps checking other transceivers. Failure of more than one program control flip-flop to reset indicates possible failure in the repeater ring circuits.



DECADE STATIC OUTPUTS, PM LINES AND PM ADAPTOR ADDED. J Cummings 3-21-45 | 1

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ACCUMULATOR INTERCONNECTION DIAGRAM

MATERIAL	FINISH	SCALE
/	/	/

Drawn by	Checked by	Approved by	
JLp	J Cummings 7-2-45		PX-5-302

V. HIGH SPEED MULTIPLIER

5.1 Multiplier Circuits

The circuits of the multiplier are located on three panels. The interconnection diagram, PX-6-301, shows the position of the various circuits and the following table gives the numbers of some of the pertinent drawings.

Table 5.1

PLUG-IN UNITS OF THE MULTIPLIER

Number used	Name	Wiring Diagram	Test Charts
24	Transceiver	PX-5-147	PX-5-129
6	Buffer Units	PX-6-107	PX-6-130
2	Receiver	PX-5-148	PX-5-128

5.2 Testing Procedure

The multiplier lends itself nicely to a routine automatically programmed test. The details of this test are given in the ENIAC Operating Manual.

In case of failure in the above test, the program should be stepped through by one addition time steps and the partial products appearing in the product accumulators inspected. This procedure if done in conjunction with tracing the numbers course through the multiplier (by use of the block diagram, PX-6-308) may locate the failure. If this fails to locate trouble, step by addition times to the region of failure, then by pulse times.

Table 5.2

CHASSIS DRAWINGS

Name	Position		Wiring	Test Charts
	Panel	Tubes		
Ier Selector	1	3 - 20	PX-6-101	Static:
R.H. Multiplier Table	1	21 - 40	PX-6-102	Panel 1 PX-6-122
L.H. Multiplier Table	1	41 - 60	PX-6-103	Panel 2 PX-6-126
Ier Top Chassis	3	1 and 2	PX-6-105	Panel 3 PX-6-128
Gate	2	41 - 60	PX-6-108	Dynamic:
Gate	3	41 - 60	PX-6-109	Panel 1 PX-6-123
Icand L.H. Selector	2	21 - 40	PX-6-110	Panel 2 PX-6-127
Icand R.H. Selector	2	3 - 20	PX-6-110	Panel 3 PX-6-129
R and L Shifter	2	3 - 20 and 21 - 40	PX-6-111	

By checking the pulse groups arriving at the product accumulators (and comparing this with the actual products of the digits of the numbers being multiplied) bad tubes may be found.

5.3 <u>Possible Failures</u>

1) Failure of gate tubes in multiplier selector would cause table to pass nine pulses.

2) Failure of gate tubes in multiplicand selector or in shifter would cause zero pulses to arrive at the corresponding place in the partial product.

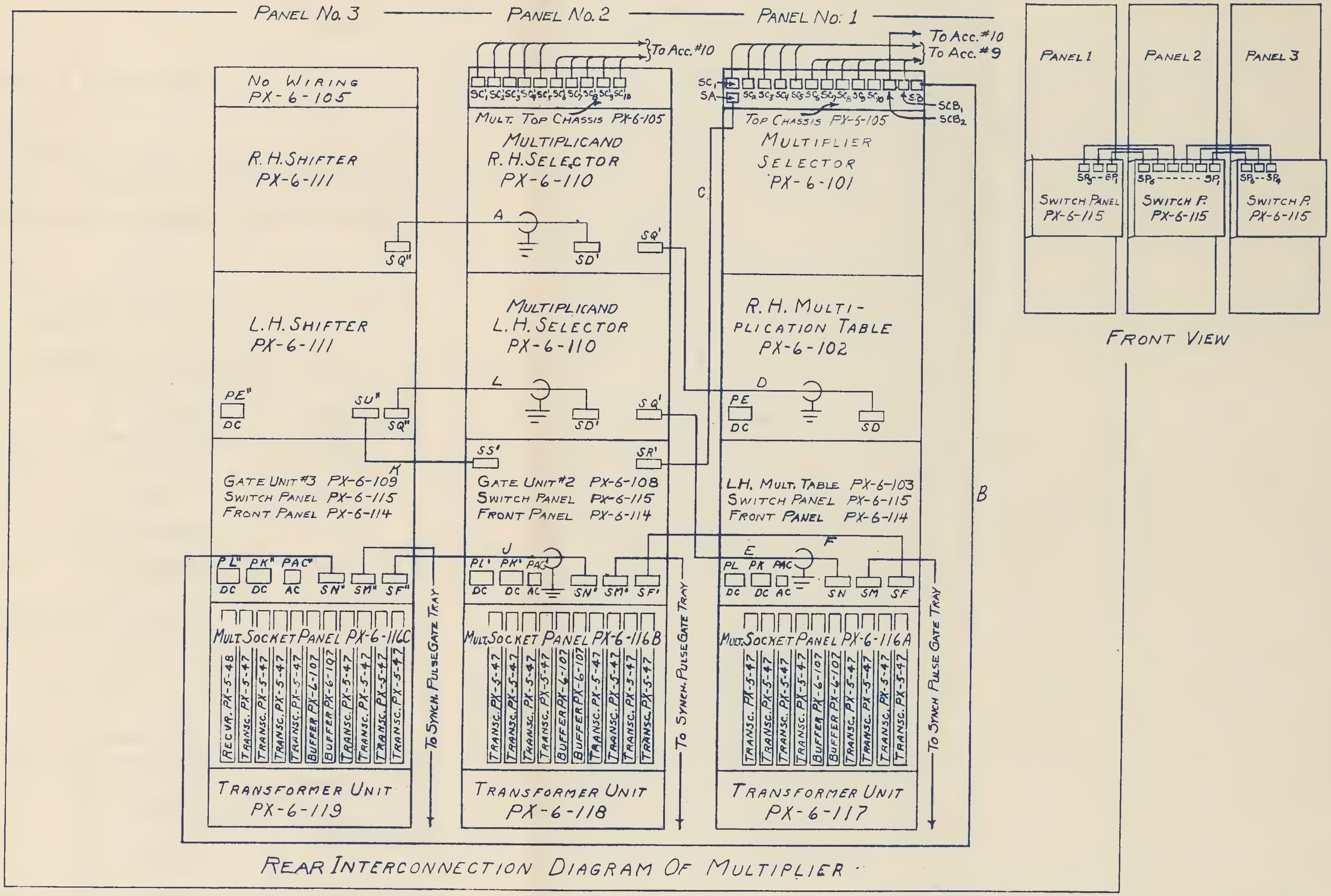
3) Failure of buffer or inverters in the channels may cause either of the above effects.

4) Failure of table output gates would cause 1, 2, 2', or 4 pulses to fail to reach the product accumulator.

5) Failure of drivers on the output would cause a digit to be missing from each partial product.

6) Failure of program control transceivers.

7) Failure of common programming circuits.



Semi-Final Revision
Added: SC₁ to SC₁₀ & SC'₁ to SC'₁₀ Front View - Interconnecting Cables, SP₁ to SP₆, Synch. Pulse Gate Line to Tray, Front and Switch Panel Identification on Third Gate Chassis Down, Each Panel. Lines Between SB & SCB₁ & SCB₂ Removed.
8-18-45

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INTERCONNECTION DIAGRAM OF HIGH-SPEED MULTIPLIER

MATERIAL	FINISH	SCALE
/	/	/

Drawn by:	Checked by:	Approved by:	
CJMcC Jan. 8, 1945	F. Robt. Michael Aug. 17, 1945	[signature] 8-18-45	PX-6-301

VI. DIVIDER AND SQUARE ROOTER

6.1 Divider and Square Rooter Circuits

The following tables give the numbers of some of the pertinent drawings of the divider and square-rooter. PX-10-303 shows the positions of the chasses and the plug-in units.

Table 6.1a

DIVIDER AND SQUARE ROOTER PLUG-IN UNITS

Number of Units	Name	Wiring	Test Charts
10	Receivers	PX-5-148	PX-5-128
8	Transceivers	PX-5-147	PX-5-129
2	Buffers	PX-6-107	PX-6-130
1	Repeater	PX-5-149	PX-5-130
1	Decade Ring (Master Programmer)	PX-8-101	PX-8-125

Table 6.1b

DIVIDER AND SQUARE ROOTER CIRCUITS

Name	Position	Wiring	Test Charts
Gate No. 1	3 - 20	PX-10-106	Static: PX-10-115A-D
Gate No. 2	41 - 60	PX-10-105	
Top	1 and 2	PX-10-112	Dynamic: PX-10-116A-C

6.2 Checking the Operation

Since the divider and square rooter works in conjunction with a number of accumulators the first thing to do is to systematically check all

these accumulators (see Chapter IV).

Drawings PX-10-403 and PX-10-404 show the numbers occuring at various places in the accumulators during sample division and square root problems. These problems may be done at one addition rate after a failure is indicated.

Since part of the control circuits go to accumulators via cables and trays the operator should carefully check these when trouble is suspected. The presence of the proper adaptors, et cetera, should be verified.

Note that the square root of zero is the simplest test problem that the unit can be caused to do.

6.2.1 Program Control Failures

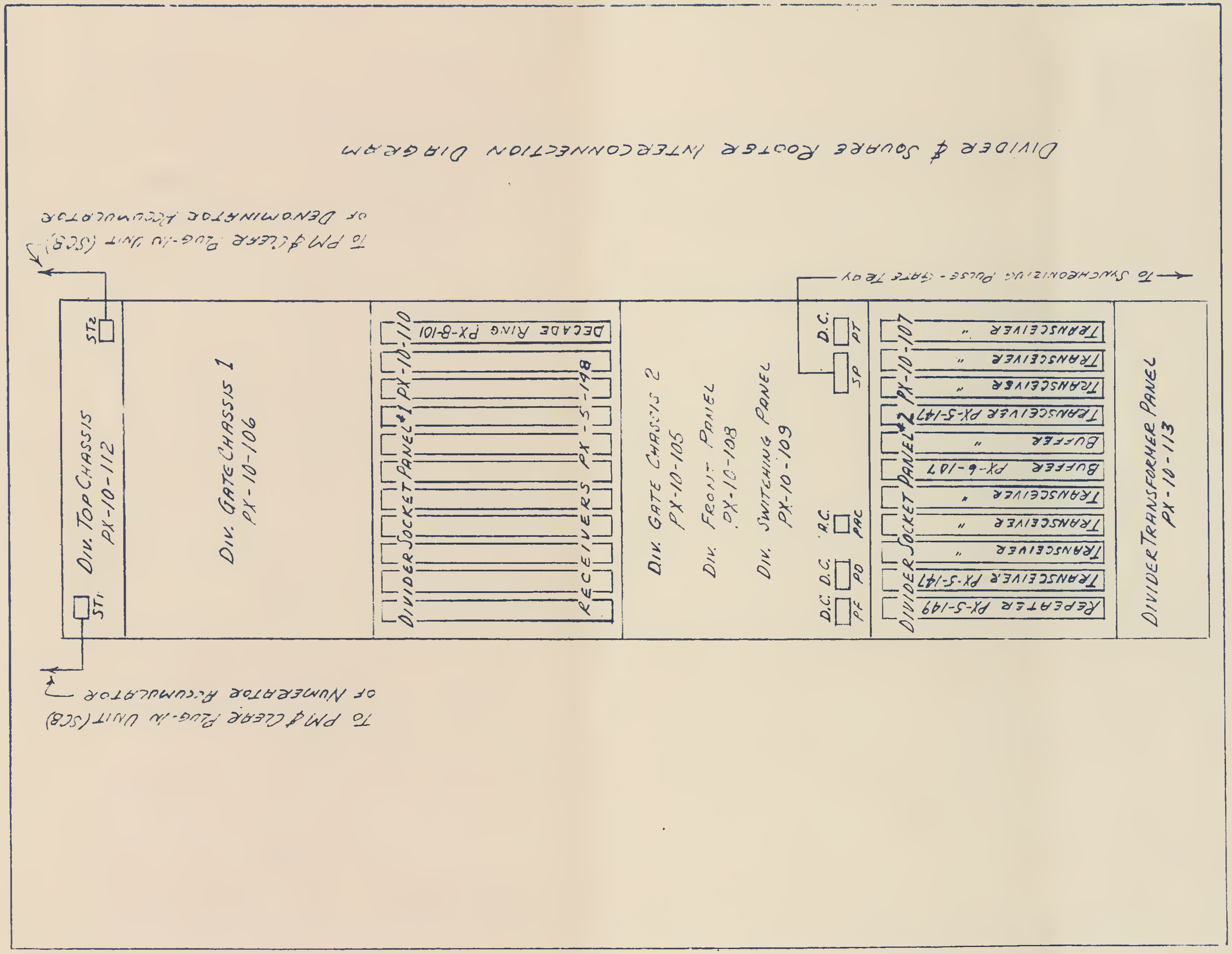
If any transceiver remains "on" then it should be replaced. If more than one remains on, then the common programming circuits should be inspected. Check in particular to see if the program ring cycles as it should. If the program ring cycles as it should, inspect the clearing circuits.

6.2.2 Numerical Circuit Failures

Check the quotient place ring and the various pulse gates including the ± 1 or ± 2 receivers.

6.2.3 Common Programming Circuit Failures

Using the block diagram and a sample division or square root problem the operator should proceed at one addition time (and perhaps repeat at one pulse time rate) rate and note the first circuits which fail to operate (as indicated by the neon lights on the front panels). Reference should be made to PX-10-302.



REVISIONS		
PX-8-101 ADDED AT DECADE RING.	5-1-46	1

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DIV. INTERCONNECTION DIAGRAM

MATERIAL	FINISH	SCALE
/	/	/

Drawn by	Checked by	Approved by:	
JLP 6/29/45	C. [signature]		PX-10-303

TABLE 6-2

DIVISION - ILLUSTRATIVE PROBLEM

Problem: Divide P 0 2090070 000 by P 0 230 000 000. Round answer off to 4 places. No interlock,

Period	Add. Time	Quotient Accumulator		Numerator Accumulator		Denominator Accumulator	Shift Accumulator	
		Receives	Stores after Receiving	Receives	Stores after Receiving	Receives during period 1 and stores thereafter.	Receives	Stores after Receiving
I	1			P 0 209 070 000	P 0 209 070 000	P 0 230 000 000		
	2							
	3							
II	4			M 9 770 000 000	M 9 979 070 000			
	5	P 0 100 000 000	P 0 100 000 000					
shift	6						M 9 790 700 000	M 9 790 700 000
	7			M 9 790 700 000	M 9 790 700 000			
	8			P 0 230 000 000	P 0 020 700 000			
	9	M 9 990 000 000	P 0 090 000 000					
shift	10						P 0 207 000 000	P 0 207 000 000
	11			P 0 207 000 000	P 0 207 000 000			
	12			M 9 770 000 000	M 9 977 000 000			
	13	P 0 001 000 000	P 0 091 000 000					
III	14						M 9 770 000 000	M 9 770 000 000
	15			M 9 770 000 000	M 9 770 000 000			
	16			P 0 230 000 000	P 0 000 000 000			
	17			P 0 230 000 000	P 0 230 000 000			
	18			P 0 230 000 000	P 0 460 000 000			
	19			P 0 230 000 000	P 0 690 000 000			
	20			P 0 230 000 000	P 0 920 000 000			
	21							
	22	P 0 000 000 000	P 0 091 000 000					
IV	23							
	24	Program output pulse and answer disposal signal is transmitted						
	25	Answer is transmitted from quotient accumulator.						

PX-10-404

TABLE 6-3

SQUARE ROOT - ILLUSTRATIVE PROBLEM

Problem: Find $\sqrt{P\ 0\ 081\ 360\ 400}$. Round answer off to 4 places. No interlock

Period	Add. Time	Numerator (Radicand) Accumulator		Denominator (2 root) Accumulator		Shift Accumulator	
		Receives	Stores after receiving	Receives	Stores after receiving	Receives	Stores after receiving
I	1	P 0 081 360 400	P 0 081 360 400				
	2 3						
	4			P 0 100 000 000	P 0 100 000 000		
II	5	M 9 900 000 000	M 9 981 360 400				
	6			P 0 200 000 000	P 0 300 000 000		
shift	7			M 9 900 000 000	P 0 200 000 000	M 9 813 604 000	M 9 813 604 000
	8	M 9 813 604 000	M 9 813 604 000	M 9 990 000 000	P 0 190 000 000		
	9	P 0 190 000 000	P 0 003 604 000				
	10			M 9 980 000 000	P 0 170 000 000		
shift	11			P 0 010-000 000	P 0 180 000 000	P 0 036 040 000	P 0 036 040 000
	12	P 0 036 040 000	P 0 036 040 000	P 0 001 000 000	P 0 181 000 000		
	13	M 9 819 000 000	M 9 855 040 000				
	14			P 0 002 000 000	P 0 183 000 000		
III	15			M 9 999 000 000	P 0 182 000 000	M 8 550 400 000	M 8 550 400 000
	16	M 8 550 400 000	M 8 550 400 000				
	17	P 0 182 000 000	M 8 732 400 000				
	18	P 0 182 000 000	M 8 914 400 000				
	19	P 0 182 000 000	M 9 096 400 000				
	20	P 0 182 000 000	M 9 278 400 000				
	21	P 0 182 000 000	M 9 460 400 000				
	22						
	23			M 9 998 000 000	P 0 180 000 000		
IV	24						
	25		Program output pulse and answer disposal signal is transmitted.				
	26		Answer is transmitted from denominator accumulator.				

VII. FUNCTION TABLE

7.1 Function Table Circuits

The function table is located on two panels and there is the portable table which plugs into both panels. Tables 7.1 and 7.2 give some of the pertinent drawing numbers and PX-7-301 shows the location of the various circuits.

Table 7.1

PLUG-IN UNITS

Number of Units	Name	Wiring	Test Charts
11	Transceivers	PX-5-147	PX-5-129
1	Portable Table	PX-7-134 and PX-7-135	

7.2 Operation Test

A test sequence similar to that described in section 2.4 of the operating manual is set up. After initially clearing, set cycling unit to 1 add, and run through 3 or 4 complete cycles of the program, observing both the neons on upper panel of function table, and numbers in accumulators. Push initiating button, then 1 pulse-1-add button repeatedly; when program ring is on second (-2) stage, next push of button will cause argument to be sent to function table; next push should cause units ring to move 2 stages further; second push after this should cause function to be transmitted to accumulators and function table rings to be cleared.

After this preliminary check, return cycling unit to continuous operation, initially clear, and run through 100 argument values. At each stage of this process the accumulators should indicate the argument and the

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Table 7.2

FUNCTION TABLE CIRCUITS

Name	Position		Wiring	Static Test Charts	Dynamic Test Charts
	Panel	Tubes			
Top	1	1 and 2	PX-7-119	PX-7-137 A and B	PX-7-138
Upper Function Selector	1	11 - 20	PX-7-120		
Lower Function Selector	1	21 - 40	PX-7-121		
Gate	1	41 - 60	PX-7-122		
Top	2	1 and 2	PX-7-126	PX-7-139	PX-7-140
Gate A	2	3 - 20	PX-7-127		
Gate B	2	21 - 40	PX-7-128		
Gate C	2	41 - 60	PX-7-129		
Gate D	2	61 - 80	PX-7-130		

corresponding function as set up on the portable table. To check -2 and -1 arguments, set function table program switch to -2 and initially clear; then function shown for 0 argument is that set on -2 row of switches and that shown for 1 argument is that set on -1 row (Note that, since correction pulse goes into argument accumulator at beginning of cycle, zero argument cannot be transmitted immediately after initially clearing; to get zero argument, either cycle around until argument accumulator shows 100, or pull out argument input cable at function table). To check 100 and 101 arguments, set program switch to +2 and cycle around until argument accumulator shows 98 and 99 respectively.

If in the preceding tests the program switch is set to "subtract" instead of "add", leaving all subtract pulse switches at "0", the function transmitted should be the nines complements of the numbers set on the switches.

7.3 Test Procedure

7.3.1 Rings - frequency

To check frequency tolerance of rings, pull out tubes specified and feed variable oscillator output to pin 8 of socket from which tube was removed in case of argument register; pin 3 in case of program ring; use a series condenser; other side of oscillator output goes to ground. Connect oscilloscope to any convenient static output; these points are the ones to which are connected wires in the cable going to neon bulbs on front panel. Rings should count at frequencies up to 180 kc.

To test ring	Pull out tubes
Units	D42
Tens	H42
Program	D49, E49, F49

7.3.2 Rings Voltage Tolerance

Use adaptor made for this purpose together with variable power supply; rings should be cycled continuously at 100 kc using variable frequency oscillator as in checking frequency tolerance. Rings should count at voltages from 120 to 300 volts.

7.3.3 Oscilloscope Check of Function Table Outputs

As additional check on operation, set up continuous program. No argument is used. Observe output by plugging triple connector into output socket, with a tray load box plugged into one of the three outputs; the scope probe can then be inserted in one of the other outputs. With program set to 0 and "add", the number of pulses observed on each channel should be the same as the number set on the corresponding switch. Operation of subtract pulse switches can be checked by observing appearance of 1' pulse on an output channel when corresponding subtract pulse switch is set to "S". On PM channels, 9 pulses should appear if either table or master switch is set to "M". PM positions on constant switches are most conveniently checked by observing result of changing corresponding master PM switch from "P" to "M" or vice versa.

7.4 Trouble Shooting Procedure

In the following list will be found a number of cases of abnormal operation together with their probable causes and remedies. Before making

any other tests, see that no switches are set half-way between detent positions.

a. All rings operate continuously - may be defective transceiver; check to see if any transceiver neons remain on. If only one remains on, replace defective unit. If more than one remain on, check clear gates (A48, B48, C48) and clear tubes (A49, B49, C49); also initial clear buffer (D48).

b. Program ring cycles continuously but argument register remains cleared - check repeater input gates (D49, E49, F49).

c. Program ring fails to cycle - check as in b. above; also check pulse former tubes (G49, H49, J49). Also check ring tubes, particularly if ring stalls on any except first stage.

d. Argument is not received but shifting takes place normally - check tubes K48, L48; if only one digit of argument is received, check D42, H42.

e. Neither argument nor shift pulses received - check pulse formers (B42, C42, A41; also J42, K42, L42). Check ring tubes if this fails; if ring stops on any except first stage (zero position), it is almost certain that a ring tube is defective.

f. Erroneous transmission or failure of transmission for ten adjacent argument values, others OK - check corresponding selector input gates (on top chassis of panel 1).

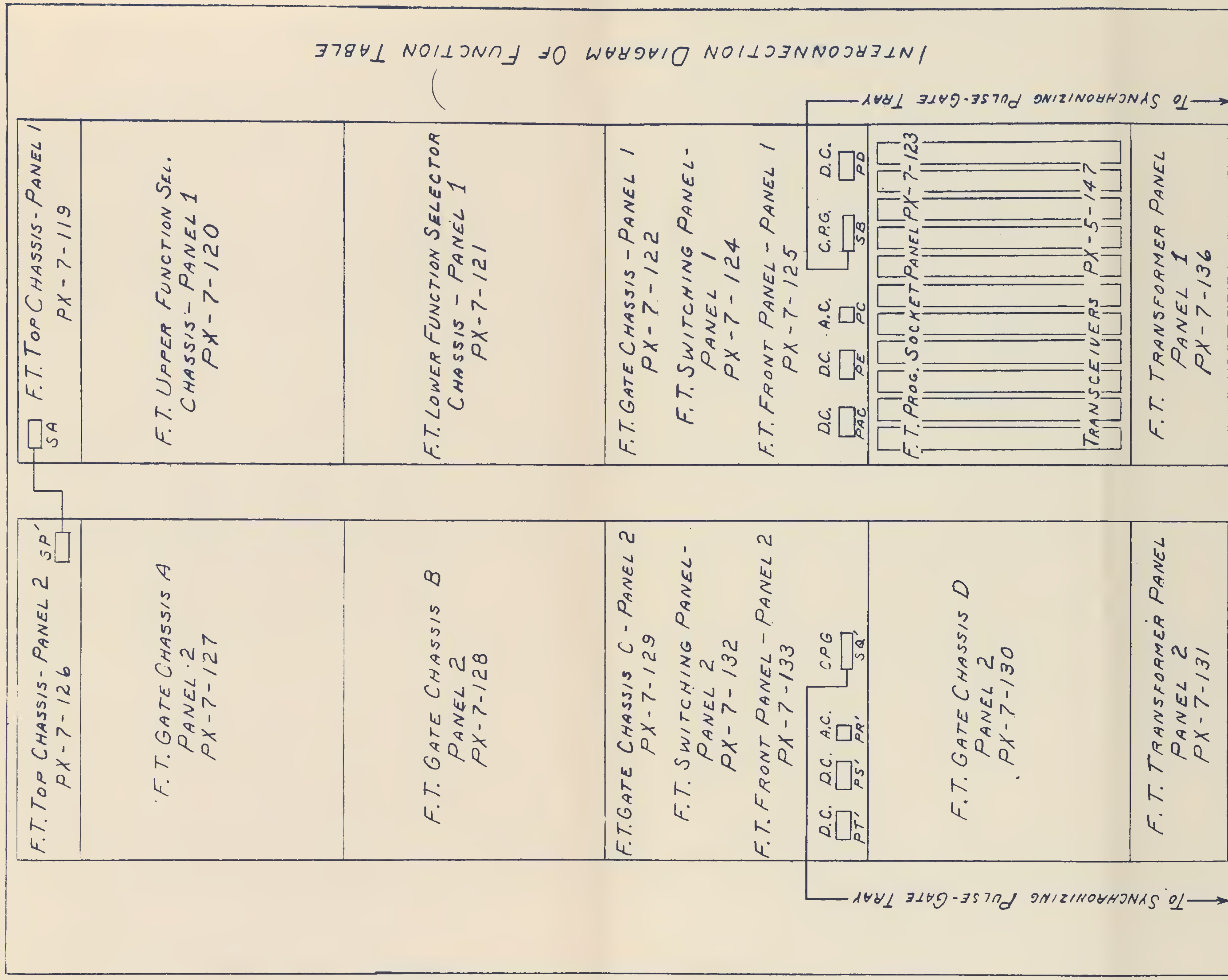
g. Erroneous transmission or failure of transmission for all arguments having a given units digit (for example, 8, 18, 28, 38, etc.) - check vertical drivers (row 26 on panel 1).

h. Combination of f. and g. - check 807 selector tube at intersection of defective row and column.

i. No number transmitted on a given digit channel - check tubes corresponding to that digit which appear in block marked "table controlled digit output channel" or "master switch and constant transmitter" on drawing PX-7-118. If PM channel is defective, check corresponding tubes.

j. Failure of a given figure to be transmitted on any channel - check corresponding tubes on panel 2 (see block marked "output gates and driver circuits" on drawing PX-7-118).

k. Spurious transmission on a given digit channel - check corresponding output gate inverters and output gates.



REVISIONS

GENERAL REVISIONS.

SEMI-FINAL REVISION. 1

RFShaw 6-27-45

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FUNCTION TABLE INTERCONNECTION DIAGRAM

MATERIAL	FINISH	SCALE
	/	

Drawn by:	Checked by:	Approved by:	
CJMcC JAN. 8, 1945	RFS 9 June 44	RFS 27 June 45	PX-7-301

VIII. CONSTANT TRANSMITTER AND IBM READER

8.1 Circuits of the Constant Transmitter

The following tables give the drawings pertinent to maintaining the constant transmitter. PX-11-301 shows the location of the various plug-in units and chasses.

Table 8.1

PLUG-IN UNITS

Number Used	Name	Wiring	Test Charts
30	Transceivers	PX-5-147	PX-5-129
2	Pulse Boosters	PX-11-115	PX-11-125

8.2 Operation Test

An operation test is described in section 2.6 of the operating manual. The actual test cards (with nines punches) should be used here since (due to the "1", "2", "2'", and "4" channels) the constant transmitter may operate correctly with certain numbers but not others.

The various program controls can be checked by repeating the above test and successively using different program controls.

Note that the PM circuits of groups J_{LR} and K_{LR} were originally wired so as to provide the correct pulse automatically. This would mean that negative numbers would be set up as complements with respect to 10^n-1. The various manuals instruct the operator to set up negative numbers as complements with respect to 10^n. This means that the tubes A'29, A'30, A'70

Table 8.2

CHASSES AND RELAY CIRCUITS

Name	Position		Wiring	Static Test Charts	Dynamic Test Charts
	Panel	Tubes			
Top	1	1 and 2	PX-11-101A	PX-11-121	PX-11-122
Gate	1	41 - 60	PX-11-104		
Top	2	1 and 2	PX-11-101B	PX-11-123	See note below
Gate A	2	10 - 20	PX-11-108		
Gate B	2	21 - 40	PX-11-109		
Gate C	2	41 - 60	PX-11-110		
Gate D	2	61 - 80	PX-11-111		
Relay Strip	3		PX-11-118		

Note that there is no dynamic test chart for panel two. These circuits, being relay controlled, operate too slowly to be observed on an oscilloscope.

and A'71 should be removed from the constant transmitter. Note that these tubes are shown on the wiring diagrams but not on the block diagram, PX-11-307.

8.3 Possible Failures in Constant Transmitter

Possible faults, their probable causes and cures, are listed below.

a. Failure to transmit anything on one digit channel, regardless of group used - check corresponding column of tubes on gate chassis of panel 1 (see cross-section).

b. Erroneous transmission of one digit in a particular group - check corresponding matrix gate on panel 2.

c. Erroneous transmission of one digit in several groups - check corresponding pulse gate inverters on panel 2.

8.4 The IBM Reader

If the operation test shows failures which are not caused by tube failures such as indicated above (section 8.3) then the relay circuits should be checked.

A crank can be used to slowly turn the reader through a card cycle and someone can watch the coding relays CC_1 to C_8 on the schematic diagram on PX-11-116) and the digit relays (see PX-11-309).

If all these relays operate properly but the constant transmitter does not transmit the proper number then the gate chasses should be rechecked, and perhaps a static test (using the static test chart) is indicated.

If the coding relays do not operate properly check the coding cams in the reader (or call an IBM service man to do this).

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

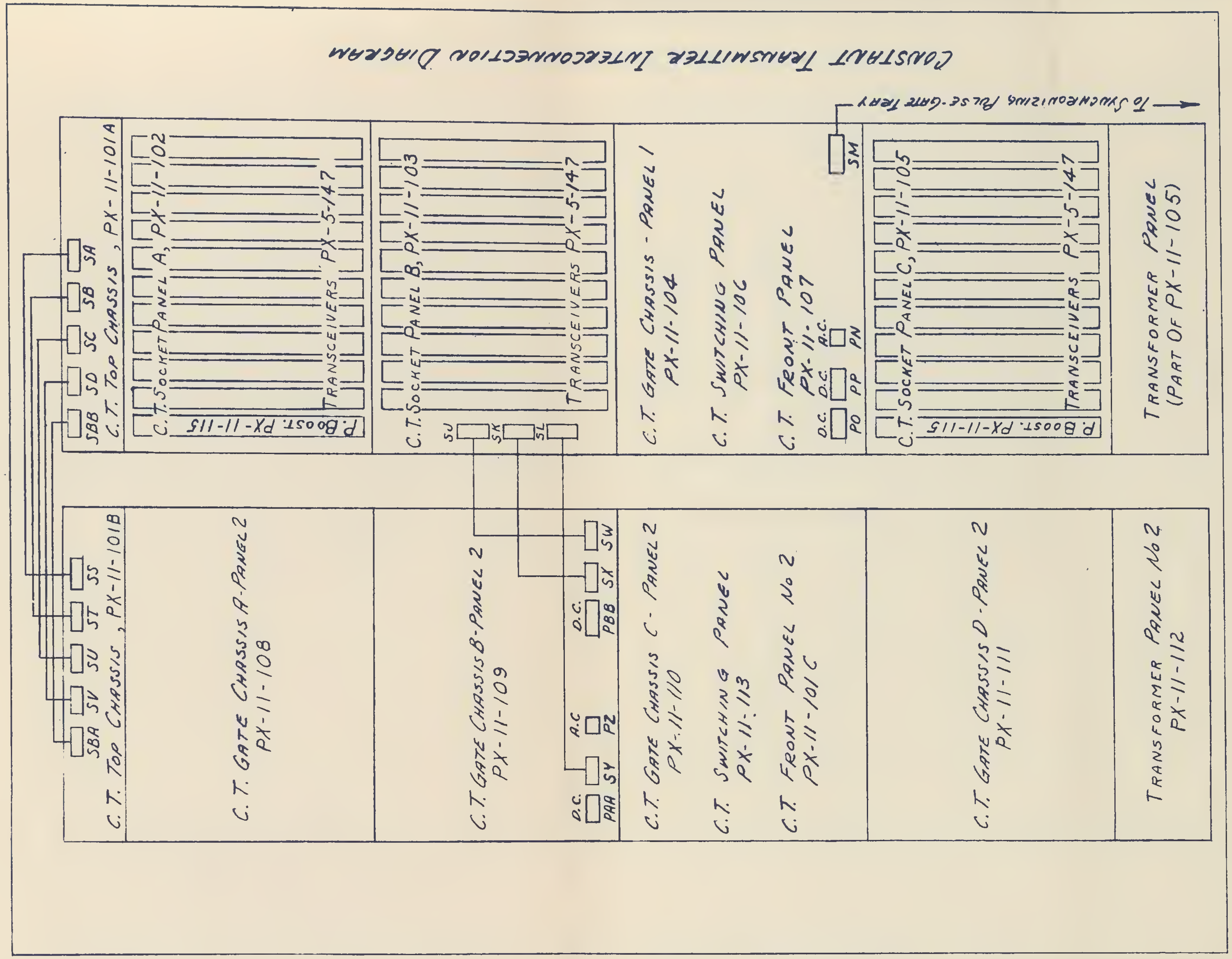
[illegible]

[illegible]

[illegible]

Also check the IBM reader plug-board for a loose connection in case of failure in one channel.

For general failures in the IBM reader call the IBM service man. In all such cases it is the responsibility of the maintenance personnel to definitely locate the failure as being in the IBM reader proper.



REVISIONS

SOCKETS ON PX-11-101A & B CORRECTED; ALSO PLUGS ON PX-11-109 & PX-11-104.

1 — SEMI-FINAL REVISION 6/22/1945

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CONSTANT TRANSMITTER INTERCONNECTION DIAGRAM

MATERIAL	FINISH	SCALE
	/	/

Drawn by:	Checked by:	Approved by:	
CJMcC JAN. 4, 1945	RFS 9 Jan 44		PX-11-301

IX. THE PRINTER AND IBM PUNCH

9.1 Circuits of the Printer

The printer contains no plug-in units. The gate chasses and relay circuits are listed in the following table.

Table 9.1

PRINTER CIRCUITS

Name	Position		Wiring	Test Charts
	Panel	Tubes		
Gate A	2	3 - 20	PX-12-104	Static: PX-12-111
Gate B	2	21 - 40	PX-12-105	
Gate C	2	41 - 60	PX-12-106	
Gate D	2	61 - 80	PX-12-107	
Relay Strip	1 and 3	1 - 80	PX-12-103	
IBM Punch			PX-12-112	

9.2 Test Procedure for the Printer

Inspection of PX-12-307 shows that the printer contains a tube for each digit in each column of the card besides the PM circuits. This means that any systematic check of the printer must involve the transmission of all possible digits to all the accumulators (or master programmer) from which printing is done and a card printed after each transmission. Since it is not advisable to punch the same number in all columns of a card a testing sequence similar to the following is suggested.

Cards should be prepared as follows. In some ten digit group, say corresponding to A_{LR}, in the constant transmitter, the following numbers

should be punched.

(1) P 0123456789
(2) P 1234567890
(3) P 2345678901
. . . .
(10) P 9012345678
(11) M 0123456789

These cards are then placed in the IBM reader and the programming arranged as follows:

1) IBM reader reads the first card.
2) The numbers of A_{LR} are transmitted to all accumulators which participate in the printing. It is also suggested that at each card reading one's be transmitted into all decades of the master programmer which participate in the printing.
3) The printer prints the number in the accumulators and the master programmer.
4) The accumulators are selective cleared.
5) The process repeats until all the cards have been read.

Note, that if, due to the type of problem on the ENIAC, it is inconvenient to selective clear all the accumulators involved, the cards for the reader may be prepared as follows.

(1) P 01234 56789
(2) P 11111 11101
(3) P 11111 11011
(4) P 11111 10111
. . . .
(10) P 01111 11111
(11) P 11111 11111

The cards punched in the above test may be compared visually or they may be compared with a standard set in the reproducing punch.

9.3 Types of Failure and Remedy

1) Failure of motor generator on punch

   a) Check a-c power supply.

   b) Check interconnection to ENIAC.

2) Failure of punch to operate when programmed.

   a) Card magazine empty.

   b) Card hopper full.

   c) Failure of starting circuits in initiating unit. (see Chapter II).

   d) Failure of starting relay in printer (PX-12-103).

   e) Failure of punch starting circuits (PX-12-112).

3) Punch continues to operate.

   a) Starting circuits in initiating unit (see Chapter II).

   b) Check reset cam in punch (PX-12-112).

4) Punch operates but fails to feed a card.

   a) Check condition of bottom card in magazine..

   b) Possible mechanical failure in feed mechanism. Call IBM service department.

5) Punch fails to punch card.

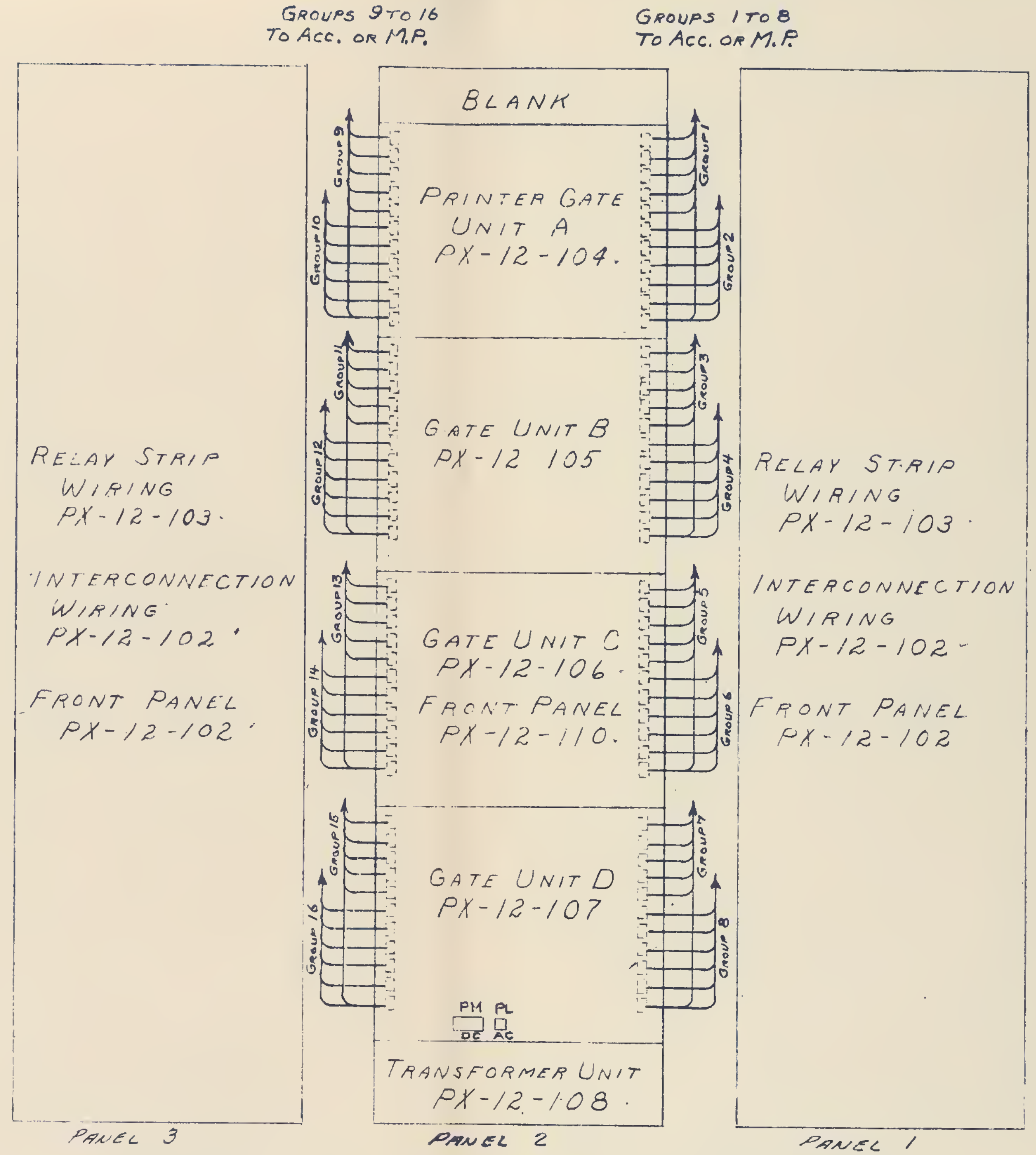
   a) Inspect digit relays (PX-12-103) back of panels No. 1 or No. 3 to see if these pick-up. If these pick-up and card is not punched then failure is in IBM punch or interconnection cable. If these fail to pick-up then check starting relay (PX-12-103) and interlock cam. If these

pick-up but fail to hold check holding cam.

6) Fails to punch in a particular column. Check the corresponding tube, relay, or jumper connection on plug-board. (See PX-12-104 to 107, PX-12-103, PX-12-305.)

7) Multiple punches in some columns. Check against multiple program pulses circulating in the ENIAC. Check tubes in the associated columns.

8) Intermittent extraneous punchings. Check associated relays for spring tension. Vibration may cause the relay to gradually pick up.



INTERCONNECTION DIAGRAM OF PRINTER

GROUPED, STATIC INPUT CABLES TO PRINTER ADDED J. Cummings 5-21-45	1

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PRINTER INTERCONNECTION DIAGRAM

MATERIAL	FINISH	SCALE
/	/	/

Drawn by:	Checked by:	Approved by:	
CJMcC APRIL 6, 1945	J Cummings 4-9-45		PX-12-304

X. MASTER PROGRAMMER

10.1 Circuits of the Master Programmer

Note that 10 of the master programmer transmitters are located on the cycling unit, see PX-1-301. The following tables give a list of the plug-in units and chassis circuits of the master programmer.

Table 10.1

PLUG-IN UNITS

Number of Units	Name	Wiring	Test Charts
20	Decade	PX-8-101	PX-8-125
10	Program	PX-8-103	PX-8-123
10	Pulse Former and Carry-over	PX-8-104	PX-8-124
20	Transmitter	PX-8-105	PX-8-122
10	Stepper	PX-8-112	PX-8-126

Table 10.2

CHASSES CIRCUITS

Name	Position		Wiring	Test Charts
	Panel*	Tubes		
Gate	1 and 2	41 - 60	PX-8-106	Static: PX-8-120A PX-8-120B PX-8-118 Dynamic: PX-8-121

*Note that the two panels of the master programmer are identical in their functions. Thus the gate chasses are identical on the two panels. However, the plug-in units are not arranged the same, some being on the cycling unit panel.

10.2 Operation Tests

Most tests can be made using only the initiating pulse.

a. Initially clear. Feed initiating pulse into each decade direct input in turn. Decades should step once for each pulse. If next decade to the left is coupled to the one being pulsed, it should step once each time decade being pulsed goes from 9 to 0. When decades associated in a group register number set on top row of decade switches, they should clear on next pulse.

b. Make some test on steppers, using stepper direct input. Check operation of stepper clear switch by setting to various positions; stepper should count up to position corresponding to switch setting and then clear back. Since clearing is done by CPP only 1 add time after coincidence, it appears to be caused by pulse which puts decades into final position.

c. Check stepper direct clear input by first running stepper up to some stage other than first, as in (b), and then pulsing stepper direct clear input. This should clear stepper.

d. Check overall operation of each stepper by feeding pulses to regular program input. Decades associated with program in use should register each pulse, and after a number of pulses equal to number set on top decade switches, decades should clear and stepper move up. Similar action should take place for each of the six stepper stages and each of the six corresponding sets of decade switches.

e. To check outputs, use same procedure as in d., and feed output to another program input. Output pulses, one for each input pulse,

should be obtained as long as stepper is on stage corresponding to output being used; when stepper moves up, pulses should be obtained from next output, etc.

f. If it is desired to check operation at normal speed, a continuous program can be set up using two selective clear transceivers, feeding output of each into input of the other, and use this series of pulses in tests d. and e. above. Outputs may, if desired, be observed on oscilloscope.

10.3 Trouble Shooting

Several possible faults are listed below, together with their probable causes and cures.

a. Decade or stepper fails to cycle and will not clear to first or zero stage - replace decade or stepper.

b. Decade clears but does not cycle - replace pulse former - carry-over unit.

c. Decades initially clear but fail to clear on reaching coincidence with switch settings - check coincidence gates, parallel gates, stepper output inverters; if none of these are at fault replace program plug-in unit.

XI. A.C. EQUIPMENT AND POWER SUPPLIES

11.1 Introduction

This chapter covers the following topics:

1) A.C. power and control system.

2) Starting sequence.

3) Power supplies, bleeder, and condensers.

4) Common failures.

5) Ventilating system maintenance.

11.2 A.C. Power and Control System

The complete diagram for the power and control wiring is shown on drawing PX-1-101. The rack from which the A.C. power is distributed to the ENIAC heaters, to the fans and to the power supplies is shown on PX-1-304. Simplified wiring diagrams of the power system and control circuits are shown on the following:

PX-1-303	Power System Block Diagram
PX-9-307	Cycling Unit and Initiating Unit Block Diagram.

11.2.1 Fuses

Fuse sizes are shown on the drawings as follows:

A.C. Main Fuses	PX-1-101
Power Supply Heater Fuses	PX-13-111
Power Supply Plate Fuses	PX-13-111
D.C. Circuit Fuses	PX-13-102

These d-c circuits and the power supply heater circuits use Western Electric alarm type fuses in the following sizes: 1/4 amp, 1/2 amp, 1 1/3 amp, 2 amp, 3 amp, and 5 amp. In certain cases (those marked 5S on PX-13-102) the 5 regular ampere fuse was found to be inadequate. Western Electric Company does not manufacture these fuses in larger than 5 ampere rating. The 5S fuse is made by refilling a 5 amp. Western Electric fuse (catalog No. 35H)with a new link of Advance alloy round wire, 0.0126 inches in diameter.

11.3 Starting Sequence

Drawing PX-1-112 is a chart designed to aid in locating troubles in the main power sources which may develop during either the starting operations, or during running operation but affecting the main power sources or auxiliaries (fans).

In using the chart it should be remembered that since each step is dependant on the previous step, the point at which the sequence fails should be determined so that possible troubles beyond that point need not be investigated.

When trying to locate trouble which has turned the entire machine off certain safety switches on the a-c distribution panel should be opened. This prevents any testing (by going through portions of the starting sequence) from subjecting the tubes to numerous heating and cooling cycles (which would increase the probability of failure of the tubes). If this is done certain protective relay circuits may be shunted for testing purposes without endangering the ENIAC. Furthermore, the control wiring, contactor and relay adjustment, and entire starting sequence may then be tested without turning the main power on provided the under-voltage release and phase failure relays are shunted.

11.4 <u>Power Supplies, Bleeders, and Condensers.</u>

The following drawings show the wiring from the a-c sources shown on PX-1-101 through the power supplies to the point where the d-c terminates at each unit as noted.

11.4.1 Supplies

PX-13-104	Standard Power Supply Wiring Diagram
PX-13-108	Power Supply and Wiring Diagram

11.4.2 Bleeders

PX-13-106	Power Supply to Bleeders Interconnections
PX-13-112	Bleeder Wiring Diagram
PX-13-102	D-C Voltage Chart (shows bleeder to d-c panel connections)

11.4.3 Condensers

PX-13-102	D-C Voltage Chart (shows d-c panel to condenser connections)
PX-13-109	Power Supply Condenser Wiring Diagram

11.5 <u>Common Failures</u>

11.5.1 D-C Undervoltage

If, after attempting to turn the d-c on by depressing the d-c start button, the <u>d-c trips off at the end of the 10 second initial clearing period</u>, usually the trouble is caused by an undervoltage from one of the 28 power supplies (undervoltage in supply Z will not trip d-c). Proper procedure to locate trouble is as follows:

1. Turn d-c on again by d-c start button and check power supply fuses by observing neon lamps in top of d-c fuse cabinet.
2. If 1. does not detect the trouble, place a jumper across the series stop circuit which runs through the undervoltage relays

(relays are located in one of the by-passing condenser cabinets). Turn d-c on again and note which relay fails to hold when pick-up relays drop out. Caution: 1500 volts d-c potential on some relay contacts. Check corresponding power supply for a tube with a faulty heater. Caution: After replacing a power supply tube allow 1 minute warm-up time before turning d-c on.

3. If no tubes are faulty check line fuses in power supply fuse panel, by removing pull-out block, and testing with an ohm-meter, or some other continuity checking device.

4. Do Not forget to remove jumper across undervoltage relays.

11.5.2 D-C Fuse Failures

Quite frequently the operator forgets to set the operation switch on "Continuous" before turning on the d-c. This will result in the blowing of a d-c fuse.

Locating a blown d-c alarm fuse is usually not difficult, for these fuses have indicators which stand out when the fuse has blown. Occasionally, however, the fuse wire may stretch, but not break (if it is operating near its rating) permitting the alarm contact to close and tripping the d-c off. In such cases, a persistant and close inspection may be required to locate the offending fuse. The correct sizes of fuses are shown on drawing PX-13-102.

Under certain conditions, on turning on the d-c the machine will trip off before completion of the 10 second period due to blowing a d-c fuse. The blown fuse may be caused by an undervoltage in one of the d-c supplies, and it is suggested that this possibility be investigated before assuming that the trouble is in one of the ENIAC units.

CONTROL CIRCUIT VOLTAGE		RELAY OR CONTACTOR	LOCATION OF RELAY OR CONTACTOR	PICKED-UP BY CLOSING OF	HELD THRU THESE CONTACTS IN SERIES	POSSIBLE CAUSE OF OPERATION OR FAILURE (3)	LOCATION OF HOLD CONTACTS	REMARKS
(4)	(4)							
	220	A AUXILIARY RELAY	MACHINERY LAB. BOX OF CONTACTOR B.	START PUSH BUTTON ON INITIATING UNIT FRONT PANEL SEE PX-9-302	B_1		MACH. LAB. - CONT'R B BOX	
					P_1	DOOR OPEN & SHUNT SWITCH NOT PUSHED THERMOSTAT OPERATION - SEE RELAY C BELOW.	A.C. DISTRIBUTION RACK SEE PX-1-304	
					STOP PUSH BUTTON		INIT. UNIT-SEE PX-9-302	
	220	B - ENIAC MAIN HEATERS CONT'R	MACHINERY LAB.	A_1	A_1		IN MACHINERY LAB. BOX OF CONTACTOR B	
					B_1			
	220	E - FAN CONT'R	A.C. DISTRIBUTION RACK	A_3	A_3		do	
110		AMBER PILOT LT.	INITIATING UNIT	A_4	A_4		do	
	220	D. POWER SUPPLIES HEATERS CONT'R	A.C. DISTRIBUTION RACK	E_1	Q_1	POWER SUPPLY HEATER FUSE FAILURE - SEE Q BELOW	A.C. DISTRIBUTION RACK	
					E_1			
110		F 1 MINUTE TIMER	do	D_1	ENIAC & 3 P.S. HEATER PHASE FAILURE RELAYS (1)	FUSE BLOWING OR FAILURE OF ONE OR MORE PHASES OF POWER SOURCE	do	(1) THESE RELAYS ARE ADJUSTED TO HOLD WITHOUT CHATTERING AND TO DROP OUT ON REDUCTION TO 60% OF RATED VOLTAGE
					D_1			
	220	G POWER SUPPLY PLATE CONTACTOR	MACHINERY LAB	F_1	F_1		do	(2) WILL TRIP D.C OFF AT END OF 10 SEC. INITIAL CLEARING PERIOD.
					L_1	PRESSING D.C STOP BUTTON BLOWING OF D.C ALARM FUSE PHASE OR MAIN FUSE FAILURE OF POWER SOURCE UNDER-VOLTAGE OF ONE OR MORE OF 28 D.C POWER SUPPLIES (2) PHASE OR MAIN FUSE FAILURE IN POWER SUPPLY PLATE CIRCUIT (2)		
	220	H - INITIAL CLEAR RELAY	A.C DISTRIBUTION RACK	G_1	G_1		IN MACHINERY LAB. BOX OF CONT'R G.	THE INITIAL CLEAR RELAY DROPS OUT WHEN K_4 OPENS AT END OF 10 SECOND PERIOD OF J TIMER.
					K_4			
	220	J - 10 SEC. TIMER	do	G_1	K_4		do	
	220	M - U.V. PICK UP	BY PAS. CONDENSER CAB'T	G_1	K_4		do	
	220	K - AUXILIARY RELAY	MACHINERY LAB BOX OF CONT'R G.	J_1	G_1		do	PRESSING INITIAL CLEAR PUSH BUTTON CAUSES GREEN PILOT TO GO OFF FOR 10 SECONDS WHILE H, J, M, & L RECYCLE
					K_1		do	
					INITIAL CLEAR PUSH BUTTON		INITIATING UNIT	
[illegible]		GREEN PILOT	INITIATING UNIT	K_3	K_3	INITIAL CLEARING ANY REASON CAUSING D.C TO BE OFF - SEE G ABOVE	MACHINERY LAB BOX OF CONT'R G	
110		C AUXILIARY RELAY	A.C DISTRIBUTION RACK	NORMALLY PICKED-UP	46 DOOR SWITCHES	DOOR REMOVAL OR SWITCH OUT OF ADJUSTMENT	TOP OF DOOR EA UNIT	TEMPORARILY SHUNTED
					43 THERMOSTATS	OVERHEATING CAUSED BY: 1 - DIRTY FILTERS, 2 DAMPER IN DUCT CLOSED, 3 INLET DAMPERS CLOSED, 4 FAN STOPPAGE	IN DUCT WORK ABOVE EACH UNIT	← (5) { P INTRODUCES A DELAY WHICH MAY BE SET UP TO 15 MIN. TO PERMIT TIME TO CORRECT A FAULT (SUCH AS A BLOWN FAN FUSE) BEFORE MACHINE TRIPS OFF
110		P - DELAY ENIAC TRIP TIMER	do	C_1	C_1	SEE REASONS FOR C ABOVE	A.C DISTRIBUTION RACK	←
110		L D.C CUT-OFF RELAY	do	D.C. STOP PUSH BUTTON	D.C. START PUSH BUTTON	SEE REASONS FOR L_1 OPPOSITE & ABOVE	do	RELAY IS NOT NORMALLY PICKED UP. D.C. ALARM FUSE RELAYS ARE LOCATED IN A BOX BESIDE D.C FUSE PANEL.
				D.C. ALARM FUSE RELAYS	L_2			
				N_1				
110		Q POWER SUPPLY CUT-OFF RELAY	do	P.S. HEATER ALARM FUSE RELAYS	Q_2	POWER SUPPLIES HEATERS ALARM FUSE FAILURE	do	ALL P.S. HTR POWER IS AUTOMATICALLY TURNED OFF TO PERMIT SAFE REPLACEMENT OF FUSE - USE OF SAFETY SWITCH ALSO RECOMMENDED.
					D.C START PUSH BUTTON			
110		N AUXILIARY RELAY	do	NORMALLY PICKED-UP	K_1 OR		MACHINERY LAB.	
					D.C. UNDER VOLTAGE RELAYS AND	CIRCUIT FUSE BLOWN OR TUBE FAILURE	CONDENSER CAB'T	
					P.S PHASE FAILURE RELAYS (1)	POWER FAILURE OR MAIN PLATE FUSE BLOWN	A.C. DISTRIBUTION RACK	

(3) SUCH CAUSES AS OPEN CIRCUIT DUE TO BROKEN WIRES, DIRTY OR PITTED CONTACTS, LOOSE SCREW CONNECTIONS ARE OBVIOUS, AND WILL NOT BE MENTIONED.

(4) FAILURE OF 220 VOLT CONTROL FUSES (LOCATED IN CONTACTOR B BOX IN MACHINERY LAB) WILL CAUSE MACHINE TO STOP. FAILURE OF 110V CONTROL FUSE TURNS OFF D.C. & AMBER, & GREEN PILOT LIGHTS.

(5) DROPPING OUT OF C RELAY IS INDICATED BY A BELL AND LIGHT - SEE PX-1-304.

(6) D.C. UNDER-VOLTAGE RELAYS ARE ADJUSTED TO DROP OUT WHEN VOLTAGE ACROSS RELAY + HOLDING RESISTOR DROPS TO 80% OF RATED VALUE.

MOORE SCHOOL OF ELECTRICAL ENGINEERING
UNIVERSITY OF PENNSYLVANIA

MAINTENANCE CHART
ENIAC STARTING SEQUENCE

SCALE —	

DRAWN BY	CHECKED BY	APPROVED BY	
J. CUMMINGS 4-8-46	T. K. [illegible] 5-6-46		PX-1-112

11.5.3 D-C Undervoltage Release Relays

PX-13-113 shows the connections and arrangement of these relays which are located in the by passing condenser cabinet and connected to the d-c at that point.

11.5.4 D-C Panel to ENIAC Units

PX-13-102	D-C Voltage Chart
PX-13-107	Chart for D-C Wiring in Power Trough. This chart will aid in determining what voltage appears on each terminal of the blocks located in the power wiring trough.
PX-13-115 A and B	D-C Wiring in Power Trough. Those drawings enable one to trace each voltage from the panel to the various terminal blocks at the ENIAC units on which it appears.

11.5.5 Replacement and Design Data

PX-13-103	Power Supply Drains
PX-13-104	Standard Power Supply Wiring Diagram
PX-13-108	Power Supply Z Wiring Diagram
PX-13-109	Power Supply Condenser Wiring Diagram
PX-13-110	Measurements on Chokes
PX-13-111	Power Supply Data Chart
PX-13-112	Bleeder Wiring Diagram
PX-13-114	Power Supply Specifications
PX-13-116	Power Supply Replacement Part Test Data.

11.6 Ventilation System

11.6.1 Fans

The fans used in ventilating the ENIAC are American Blower Utility Sets No. 250C.

1. Speed Adjustment.

Each fan unit is equipped with adjustable motor sheaves. The speed of these units may be increased by adjusting the motor sheave until the desired air delivery is obtained. To increase the fan speed (correct speed is 770 RPM) the movable flange of the motor sheave must be turned toward the fixed flange. An Allen wrench is provided to loosen the set-screw locking the flange. After the flange has been turned the required amount, the setscrew should be tightened locking the flange in place. Caution: The flange must be in such a position that the locking screw rests on the flats and not on the threaded protion of the hub. If necessary, the bolts should be adjusted as described below. All set screws should be carefully checked and tightened at least four times per year.

2. V-Belt Drives

Belt tension should be just sufficient to eliminate excessive sag on the slack side. To adjust the belt tension loosen the bolts holding the motor mounting plate to the vibration dampeners. The mounting plate may then be moved vertically up or down to the desired position and the bolts tightened. On unit, Model No. 250C, the motor may readily be moved horizontally for minor belt adjustments.

To replace belts, remove the belts from the sheaves, then remove the bolts from the ends of the bearing support, tilt the bearing support member until belts can be removed and the replacement made over the ends of

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

the support member. Belts may also be replaced by removing bearing cap and pulling belts through the shaft hole in bearing support.

The following are typical V-Belts to be used for replacing belts which may become worn or may break: Dayton A38, Thermoid No. 1400, Browning VRA-FHP-138.

3. Motor Bearings

The fan motors are provided with ball bearings. Ball bearings are filled with grease before leaving the factory. This grease should be replenished each six months.

Grease should be applied to the bearing from tubes which may be obtained from the Fafnir Bearing Co. or local ball bearing distributors. High pressure grease guns force too much grease into the bearings and through seals and therefore should not be used. Use only grease having the following general specifications:

1. Consistency a little stiffer than vaseline maintained with minimum change over ambient temperatures encountered.
2. Melting point preferably above 150° C.
3. Freedom from separation of oil and soap under operating and storage conditions.
4. Freedom from abrasive matter, acid and alkali.

The following greases or equivalents are recommended: Keystone 44, Master M31, Alemite 38.

4. Fan Bearings

Fans are equipped with self aligning sleeve bearings of the bronze bushing type. The oil is distributed by means of graphite packed oil grooves. Do not remove this graphite. Do not insert any piping or pipe fittings

between oil cup and bearing. Fill the bearing with a good grade of mineral oil of SAE viscosity No. 40. To fill the oil reservoir of fan bearings, place nozzle of oil can in the bottom of the oil cup, forcing in the oil until the reservoir and cup are full. For room temperature 100° F or above, use SAE No. 50 or 60. This type and grade oil is the same as used in automobile motors. Inspect bearings at least once every 30 days.

5. Failure

Should a single fan stop, this will probably be caused by a fuse blowing in the fan circuit. These fuses are located in the fan panel - see drawing PX-1-304. The fuses used to protect the fans from overloads are special, but readily available. These fuses are Bussman Manufacturing Company's 6.25 amp 230 Volt Cartridge Type Fusotrons. Only fuses having a thermal time delay charactoiristic and rated at 6.25 amperes should be used for these fans. Otherwise all motor protection (danger of burning-out windings) is lost. Another acceptable fuse is Shawmut Manufacturing Company's "Thermatrip".

Should these fuses blow a second time after having just been replaced, the motor should be inspected for causes of overload such as lack of oiling, worn bearings, tight belts, etc., and for grounds.

All fans stopping at once may be caused by a failure of the fan source of power caused by fuse operation, or manual opening of one of the circuit safety switches located on the a-c distribution rack and in back of the machinery laboratory switchboard. Fan power is unregulated and is separate from ENIAC power - see PX-1-101.

11.6.2 Air Filters

The air filters used in the doors at the rear of the ENIAC are "Dustop" air filters as manufactured by the Owens-Corning Fiberglas Corp. Similar filters by other manufacturers may be used but care should be taken to select a filter which uses a fireproof adhesive similar to the Lindall adhesive used by Owens-Corning Fiberglas Corporation.

Two sizes of filters are used: 10" x 20" x 2", and 20" x 20" x 2", two of the former being used only in those places where one 20" x 20" x 2" cannot be conveniently installed, i.e., in the bottom inlet on the two inlet doors, and in the two bottom inlets on the three inlet doors.

In the Moore School installation the 20" x 20" x 2" filters are also used in the fresh air inlet chamber.

The frequency of changing the filters depends on prevailing dust conditions and can best be determined by examination and experience. An indication of the filter's condition can be obtained by the temperature guages in the ducts above each unit. With new filters, the temperature rise in each unit will be approximately 11° F above room ambient. Should a considerably larger rise occur, and visual examination of the filter indicates that they are quite dirty, they should be changed.

11.6.3 Door-of-Unit Dampers

These dampers are those which adjust the flow of air through the above mentioned air filters. Tests have proven that for uniform temperature to exist within the cabinets, 75 % of the air should enter through the lower intake, and 25 % through the upper. The dampers should be adjusted accordingly, with the fins of the dampers so adjusted as to drive the incoming air toward the bottom of the cabinet. All fins of any one damper

should assume the same angle so as to insure the uniformity of the filter's dust collection.

11.6.4 Recirculating Dampers

The ventilating ducts are arranged with automatic dampers which tend to keep the ENIAC room at the temperature set on the controlling thermostats (the two thermostats which are set on the building wall behind accumulators 9 and 15). The dampers are so arranged that when the room temperature rises above thermostat setting, more air will be exhausted to the outside and less into the room and vice versa.

The wiring diagram for this system is shown on drawing PX-1-101. The manufacturer's (Minneapolis-Honeywell Regulator Co.) catalog numbers are also given on this drawing. In the diagram shown it may have been necessary to interchange the B and W wires to obtain proper operation. The location of the damper motor circuit fuses is shown on drawing PX-1-304.

11.6.5 Service Required by Recirculating Damper Motors

Inasmuch as all moving parts of the damper motor are immersed in oil, periodic lubrication is not necessary. The cover should be left on the motor at all times to protect the motor from dust and mechanical injury.

It should be noted that the balancing relay armature is adjusted to "make" contact on one side when the relay is de-energized.

All set screws on the motor-to-damper linkages should be checked once each month.

Listed below are causes and effects of certain conditions which may exist in the control circuit.

1. Broken red wire or blue wire in control circuit: Motor will run to the closed position and stay there.

2. Broken white wire in control circuit: Motor will run to the open position and stay there.

3. Loose or dirty contact on control potentiometer: Motor will run to the close position when the wiper on the control potentiometer is at a position where a poor contact is established.

4. Insufficient voltage: The sensitivity of the control circuit will be reduced, and the power of the motor will be materially lessened by a voltage drop.

11.6.6 Room Thermostats

<u>Setting of Room Thermostats.</u> T-92A - Turn temperature setting screw on top of thermostat until indicator points to the desired average room temperature on the scale.

<u>Adjustment of Room Thermostats.</u> Factory calibration - All thermostats are carefully calibrated at the factory and no attempt should be made to change any adjustment other than those mentioned under "Setting" unless the thermostat is found to be out of calibration after being in actual operation for several hours.

Thermostats with non-adjustable differentials (T92A) are calibrated so that the sliding contact is at the center of the potentiometer coil when the room temperature is equal to the setting of the indicator.

Care must be exercised in checking the adjustment of these thermostats since heat from the potentiometer coil affects the thermostat calibration and the reading of the cover thermometer (if used) to the extent of about 3°. The thermostat should therefore not be checked until it has been in operation with the power on and with the cover in place for at least

an hour. To check the adjustment, (this should be done as quickly as possible, before the heat from the potentiometer can be dissipated, and to prevent heat from your hands or breath from affecting the calibration) remove the cover and set the indicator to the room temperature as indicated on the cover thermometer or other reliable thermometer placed near the thermostat. Then observe whether the sliding contact is in the proper position (see preceding paragraph). If it is not, turn calibration screw (on bottom of thermostat) to the right or left as necessary to correct the adjustment (turn to the right to move slider to the right). Each 1 1/2 turns is equal to approximately 1°.

11.6.7 Thermostats for ENIAC Protection

These temperature controllers are of Minneapolis-Honeywell Regulator Company's manufacture and are rated as follows:

Remote Bulb Controller

Catalog No. T-615A

Range $+65^{\circ}$ to 140° F

5 ft. Tubing with Bulb

Method of Setting and of Adjusting

1. Turn adjusting screw at top of box until the indicator on the outside of the case is opposite the desired "cut-out" temperature. "R to W" contacts make on temperature rise - "R to B" makes on temperature fall. Scale divisions are marked numerically. Each Farenheit division (on the left) equals 10° and each Centigrade division (on the right) equals 5°. The notations "L" and "H" represent the low and high end of the scale range.

2. On T615A Controller, the differential between cut-in and cut-out temperatures may be increased by turning adjusting screw to the

right, which raises the indicator from "A" toward "H" on the differential scale. The equivalent number of degrees for each division from A to H varies with each scale range and with the point at which the indicator on the main scale is set. The approximate values however are as follows: If the main scale indicator is set near the low end (65° F) each division from "A" to "H" equals approximately 3 $2/7^\circ$, at the high end each division equals approximately 1 $3/7^\circ$.

For direct acting controls, the cut-in temperature plus the differential equals the cut-out temperature, and for reverse acting controls, the cut-out temperature plus the differential equals the cut-in temperature.

Mercury Switch Adjustment: If the operating differential of the controller is considerably smaller than that for which the indicator is set, the mercury switch may be out of adjustment. This sometimes occurs when a broken switch is replaced. Before making any adjustments, however, be sure that the difficulty is not due to the controller being "off level." Note the level indicator.

The adjustment may be checked as follows: Set the differential indicator approximately at mid-scale, and the temperature indicator so that the operating lever rests lightly against its upper stop. Press down on the left hand end of the operating lever until it is about midway between its upper and lower stops and just touches the differential lever. This movement should not cause the mercury to change ends in the switch. Further downward pressure on the operating lever will force it to the lower stop carrying the differential lever with it and will cause the switch to tilt and shift the mercury. Now, allow the operating lever to slowly return to midway between stops and note that the mercury should not shift

[illegible]

its position. Allow the operating lever to return to its upper stop and the switch should tilt back to its original starting position.

If the switch does not operate in this manner, turn the eccentric screw slightly to the right or left as necessary and re-check as outlined above.

To Replace Mercury Switch: Note that the arrangement of the contacts and flexible leads and make sure that they are in proper position when the new switch is in place. Use the point of a knife to pry the switch clip loose from the mercury switch - never attempt to break it loose with your fingers. Wrap two layers of friction tape around the switch to take the place of the ambroid cement before placing the switch in the clip. Check the adjustment as outlined above.

Correct Temperature Setting of Thermostats

The correct cut-out temperature is 120° F, for the ENIAC units. The ventilating system was designed to permit approximately 11° rise over ambient temperature with new air filters. This would permit satisfactory operation on days during which the ambient temperature was 100° F allowing a safety margin.

The equipment in the power supply and bleeder cabinets will not be endangered if the temperature rises 20° F, and so the thermostats may be set up to 130° F if found necessary.

The absolute maximum temperature to which any of the ventilated equipment can be safely subjected is 180° F, including the thermostat bulb and due consideration being given to the possibility of "hot-spots" it is felt that the aforementioned settings are reasonable.

12.1 List of Test Equipment			
Item	**Drawing**	**Quantity**	**Remarks**
Bench	PX-2-120 2-121 2-111 2-112 2-113 2-114	1	2-111 signal wiring, 2-112 power wiring, 113 switch panel, 114 fuse and by-passing, 120 transformer, 121 tube panel.
Power Supplies	PX-2-102 2-103 2-104	1	6 supplies PX-2-102 2 supplies PX-2-103 1 bleeder PX-2-104
Synchronizing Unit	PX-2-115 2-108	1	Front Panel PX-2-115 Wiring Diagram PX-2-108
Synchronizing Unit Supply	PX-2-107	1	
Test Oscilloscope	PX-2-110	1	Includes probe with 4 detachable ends. Connects to Synchronizing unit by cable.
Test Oscillator	PX-2-117	1	Connects to synchronizing unit by 1 conductor cable.
Variable Power Supply	PX-2-118	1	Connects to bench by four conductor cable.
HiPot Supply	PX-2-119	1	
Tube Tester	PX-2-116	1	
Voltohmist Jr.		1	
Simpson Meter		1	
12 Conductor Shielded Cable		2	Connects only into sockets marked "S".
12 Conductor Non-Shielded Cable		5	3 connect synchronizing unit to its supply.
4 Conductor Connection Cable		2	1 connects variable supply to bench.
2 Conductor Connection Cable		1	Connects synchronizing supply to AC
12 to 10 Conductor Special Cable		1	To connect pulse amplifier to bench
Load Box with 220 Ω resistors	PX-4-103	1	For output load on pulse amplifier.

12.1 List of Test Equipment (cont'd)			
Item	Drawing	Quantity	Remarks
Tube Circuit Plug-in Tester		2	
Plug-in Unit Pullers		2	For use in removing units from ENIAC.
Current Flow Test Set		1	Used to adjust relay-consists of tool box and contents.
Static Tester	PX-2-109	1	For use with static test charts for ENIAC panel.
Book of Photostats of Wiring and Test Drawings		1	Plug-in unit drawings.
Service Logs		3	1 for ENIAC, 2 for units.
Push Switch and Cord		1	For manual pulse devices.
Screwdriver		1	
Diagonal Cutters		1	
Long Nose Pliers		1	
Soldering Iron		1	
Variable Power Supply Adaptor		1	For connecting variable power supply to Multiplier, Cycling Unit, and Function Table panels.

12.2 Description and Maintenance

The following chart (Table 12.2) lists the uses of the outputs of the synchronizing unit illustrated in drawing PX-2-302 as used in testing the plug-in units as illustrated in drawing PX-2-301.

Table 12.2							
Plug-in Unit	Drawing		Fixed	Scope	Variable	Train	
	Wiring	Test				+	-
PM and Clear Unit	PX-5-108	PX-5-127			Clear Tubes	Trans. Tubes	PM Counter
Acc. Decade Unit	5-133	5-126			Carry Out	Trans. Tubes	Ring
Acc. Transmitter Unit	5-147	5-129	Sets F.F.		Resets F.F., transmitter		
Acc. Receiver Unit	5-148	5-128	Sets F.F.		Resets F.F.		
Acc. Repeater Unit	5-149	5-130			Ring (if trans. used)		Ring (if no trans. used)
Mult. Buffer Unit	6-107	6-130			Drives buffers		
M.P. Decade Unit	8-101	8-125				+ and – train operate MPPF unit	
M.P. Program Unit	8-103	8-123	Sets F.F.		Resets F.F.	Drives stopper gate	
M.P. Pulse Former and Carry Over	8-104	8-124				Drives PF through inv-erter	Drives PF direct
M.P. Transmitter Plug-in Unit	8-105	8-122				Drives trans. gate	
M.P. Stopper Plug-in Unit	8-112	8-126					Drives ring
C.U. Transmitter Plug-in Unit	9-102A 9-102B	9-123					Drives inverters
Reader Interlock Unit	9-103	9-124	Push button sets unsyn. F.F.		Sets syn.f.f.		Resets syn. f.f.

Table 12.2 (cont'd)

Plug-in Unit	Drawing		Fixed	Scope	Variable	Train	
	Wiring	Test				+	-
Reader Printer Starting Unit	PX-9-104	PX-9-122	Push Button resets reader f.f.		Set reader and printer f.f.		Resets printer f.f.
Initiating Pulse Plug-in Unit	9-105	9-125	Push Button sets unsyn. f.f.		Sets syn. f.f. Resets both f.f. and trans. pulse		
Reader Transmitter Plug-in Unit	9-106	9-121			Sets and resets f.f.		
Cycling Unit Delay Line and Off Beat P.S. Unit	9-130	9-139					Drives Pulse Standardizer
Cycling Unit Oscillator, Manual Pulser Unit	9-131	9-140	Push Button operates Pulse former				
Cycling Unit On-beat Pulse Standardizer and Amp-Plug-in unit	9-132	9-141					Drives Pulse Standardizer and Amp.
Constant Transmitter Pulse Booster Unit	11-115	11-125		Drives Buffer			
Pulse Amplifier	4-116	4-118				Drives Input Buffers	

12.2.1 Maintenance of Test Equipment

Static and dynamic test charts are provided for the synchronizing unit and the test oscilloscope. Their numbers are PX-2-112 and PX-2-110 respectively. The variable power supply, the test oscillator, and the regulated power supplies are essentially of standard design so that maintenance can easily be provided by direct use of the wiring drawings given in the list in section 12.1. The test bench is essentially a wiring distribution socket panel similar in most respects to the socket panels of the ENIAC proper. The fusing and AC power control features are copies of similar equipment for the ENIAC. Familiarity with ENIAC maintenance in these respects provide ample background which together with the wiring diagrams appropriate to the test equipment are all that is necessary for test equipment maintenance. However, a word should be added concerning the special tube chassis in the test bench. This chassis contains a few tubes from the accumulator gate chassis, PX-5-117, essential to the coupling of transceiver and repeater plug-in units when jointly operated as desired in testing from time to time (see illustration in block diagram PX-2-301). The circuits are direct copies of the similarly named tubes on drawing PX-5-117 and no difficulty in maintaining them will be encountered if this reference is kept in mind. The static panel tester is essentially a wiring distribution panel and no particular problems should be encountered in maintaining it. Its use is described in section 12.3 below. The tube tester contains no special equipment and can best be maintained with reference to its wiring drawing. A word of caution on the tube tester, however, is that when some of its fuses blow, erratic and unusual operation may occur so that before concluding some important failure has occurred,

the fuses should be checked. The operation of the tube tester is described in the detailed instructions engraved on its panel.

12.3 Use of Test Charts

There is provided a static and dynamic test chart for each plug-in unit as listed in section 12.1 and on drawing PX-2-123, a copy of which is inside the left panel door of the test table. Also listed on PX-2-123 are the names and wiring drawing numbers of the individual plug-in units. The description on the static-dynamic test drawing for each unit describes in detail the instructions necessary for carrying on the test program in accordance with the chart in section 12.2.

For the ENIAC "gate" panels, those sections which are not removable plug-in units, there is provided static and dynamic test charts just as there are for the plug-in units themselves. A list of these charts is given in a table at the beginning of each chapter for the units of the ENIAC under the column "Test Charts". A special static tester, PX-2-109, was designed for use with these charts. By reference to drawing PX-5-109 and the "legend" and note above the panel illustration on each static test chart, full information is found for the use of the static tester.

12.4 Use of Test Equipment with ENIAC Proper

The variable test oscillator, the variable power supply, and the test oscilloscope provide conveniences in testing the ENIAC.

12.4.1 Test Oscillator

In the cycling unit panel of the ENIAC there is a socket and switch provided so that the test oscillator may replace the crystal controlled oscillator normally used in the ENIAC. By connecting the test

oscillator, the ENIAC may be operated at faster or slower speeds providing means of checking the frequency tolerance in built-in rings, and perhaps in localizing certain types of faulty operation.

12.4.2 The Variable Power Supply

By the same token, the variable power supply may be connected into function table, multiplier, and cycling unit by the use of variable power supply adaptor, PX-4-120, to provide voltage tolerance tests on built-in rings in the ENIAC.

12.4.3 Test Oscilloscope

The test oscilloscope is especially adaptable for synchronization from the central program pulses (CPP) of the ENIAC, and a special blanking circuit also provides for turning "on" or "off" any section of the sweep by control of the central program pulses.

12.5 Plug-in Unit Test Voltages

In most instances the plug-in units are tested with the voltages given on the wiring diagrams. However, in some cases it was expedient to test at different voltages. The table below gives these changes.

Plug-in Unit	Wiring Diagram Voltagos	Tost Table Voltages
Mastor Programmor Program (PX-8-103)	+290 +220 +365 +460 +300	-180 -250 -105 - 10 -170
Master Programmor Transmitter (PX-8-105)	+ 95 +150 +230	+ 20 + 75 +150
Master Cycler Roader Printer Startor (PX-9-104)	+200	+150
Master Cyclor (PX-9-102)	-345 -475 -120 -295	0 -130 +225 + 50
Constant Transmittor Pulse Boostor (PX-11-115)	+110	+105

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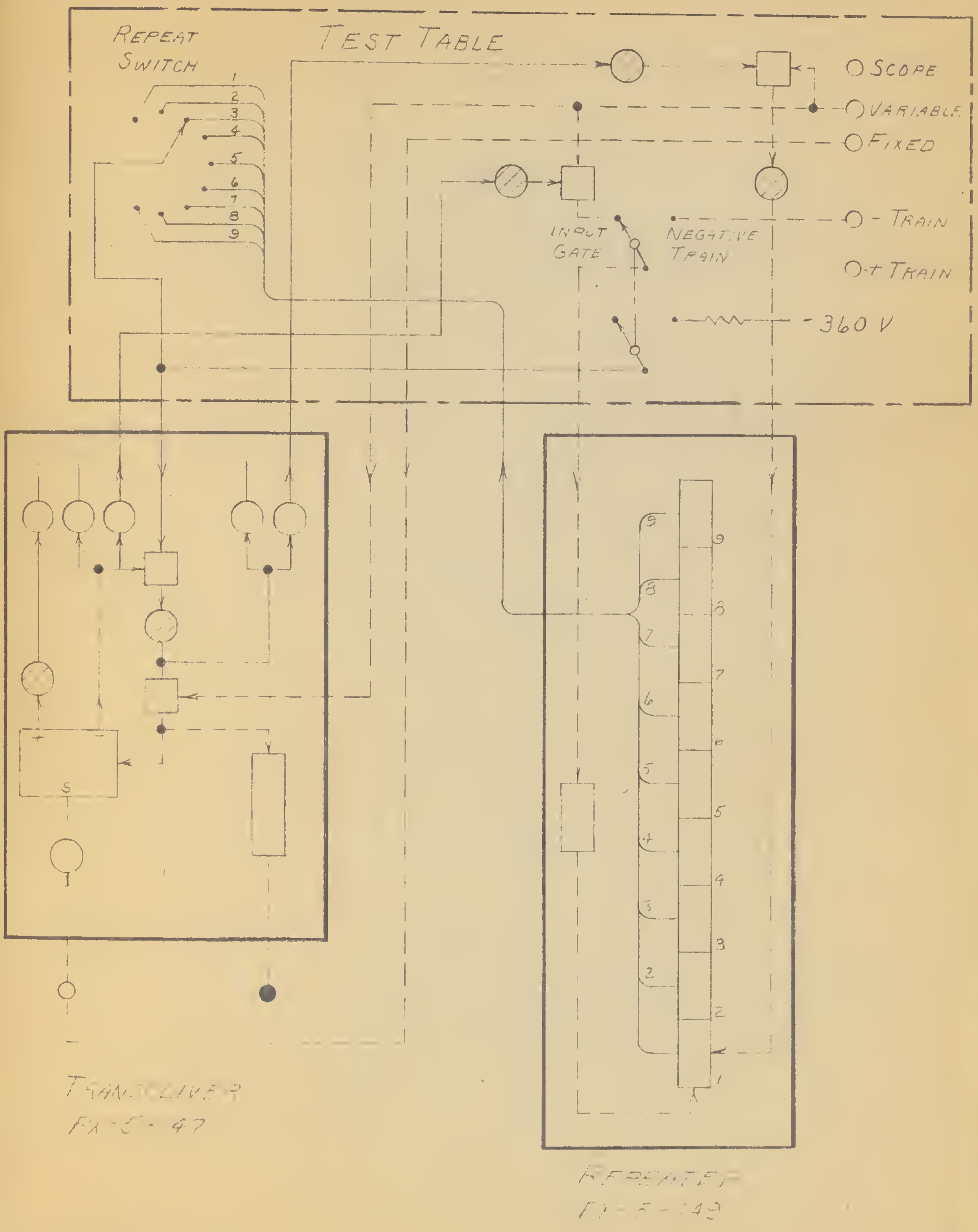
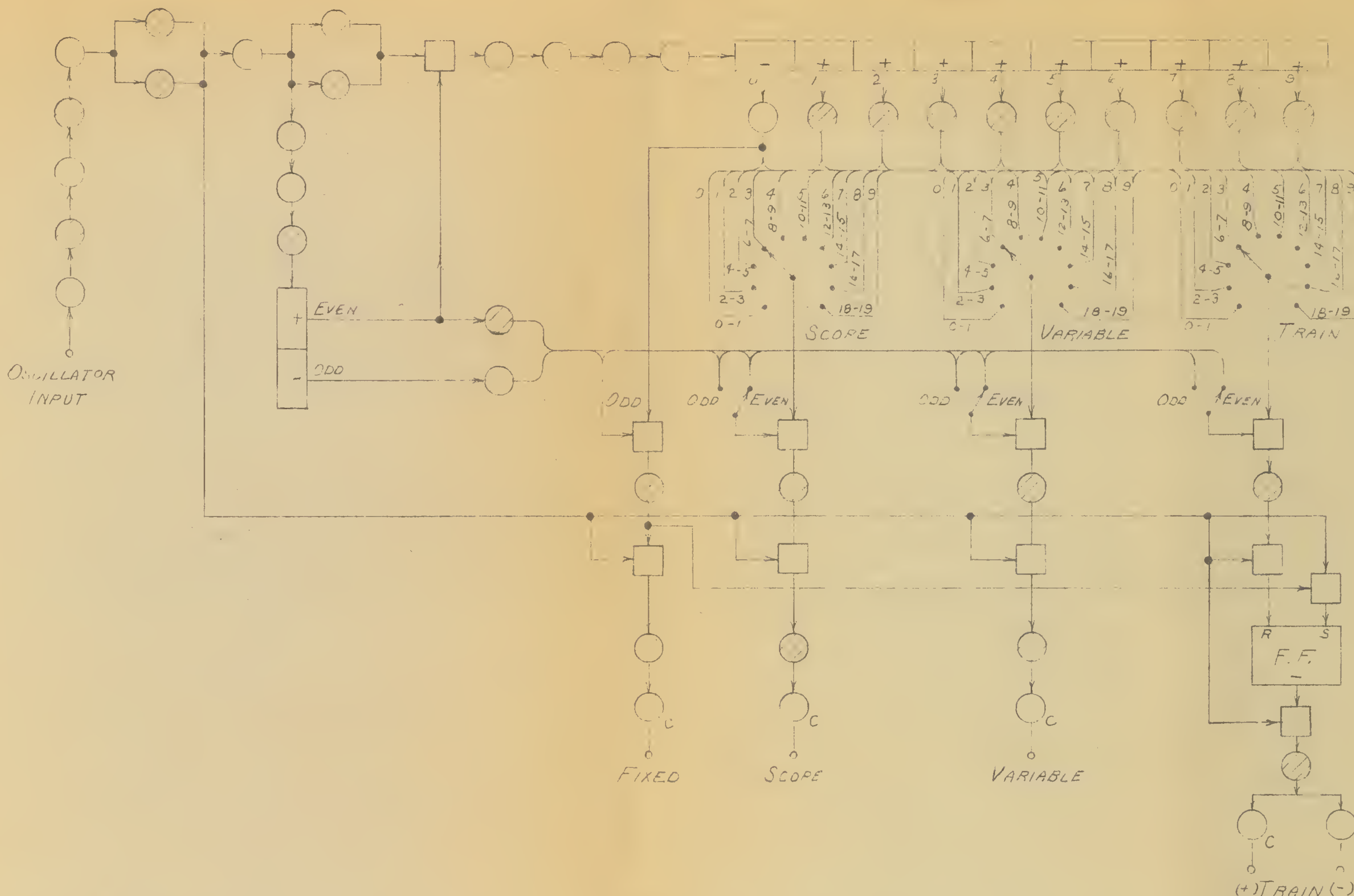


DRAWN BY			SCALE
CHECKED BY			PX-2-301
APPROVED BY			



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T.E. SYNCHRONIZING UNIT BLOCK DIAGRAM

SCALE			
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